SILICON CHIP

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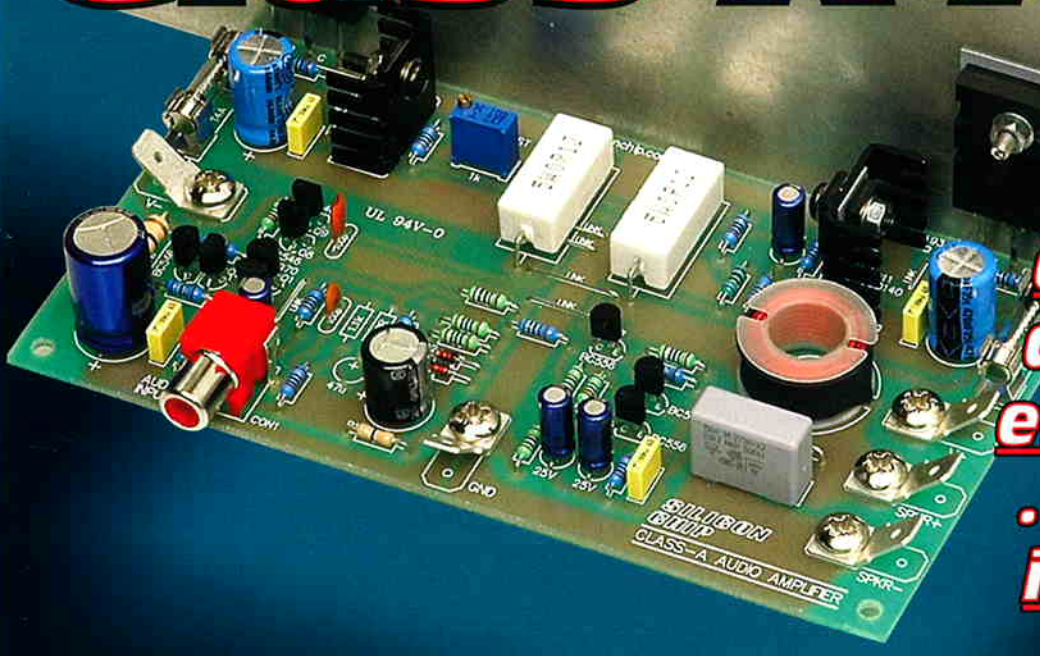

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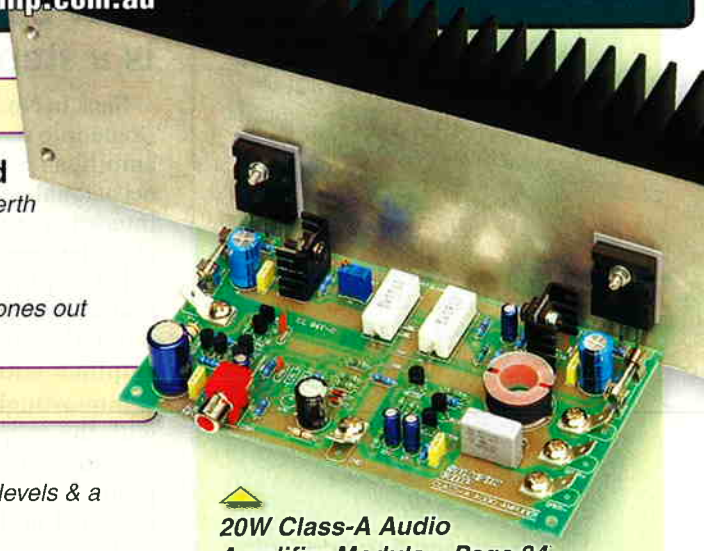

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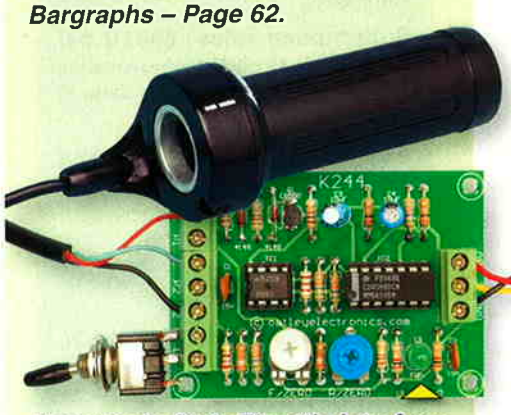

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Publisher's Letter

New 20W class-A module is a step closer to perfection

Back in November 2006 we asked the question: Do people really want a high-performance valve amplifier? Significantly, we are still getting the occasional email from people expressing their interest or otherwise. And while the consensus of the letters seems to be that people are interested in valve amplifiers, we are of the strong impression that comparatively few people would actually build the then proposed 60W/channel stereo amplifier with negative feedback.

Interestingly, we expected a number of letters expressing dissatisfaction with the proposed concept but that was not the case. A number of people also suggested an updated version of the output transformerless amplifiers produced by Cyril Murray and other designers in the late 1960s. These were designed to drive special high-impedance loudspeakers and if we were to update them, we would actually need to use an output-coupling transformer to drive conventional low-impedance loudspeakers, so there would not necessarily be an advantage to that approach.

Regardless of what approach we actually took, our previous experience leads us to expect that few people would build the final design when they were confronted with the high price and the amount of the work required to assemble the amplifier. So we decided to take the alternative approach and upgrade our very popular 15W class-A amplifier which was featured back in 1998.

We approached this with some trepidation because we well remember the problems we had with the power supply and the lengths we had to go to obtain satisfactory low residual noise. The problems were based on the heavy fixed current drain from the power supply and the relatively large hum field produced by the toroidal transformer because of that high current.

However, I am delighted to report that our efforts have borne fruit. As a result of some very careful analysis of the 1998 design by Peter Smith and drawing on some circuit techniques advocated by noted audio designer Douglas Self, we have been able to get some very significant improvements, as well as a little more power, while keeping overall power dissipation to levels similar to the old design. This has been achieved by quite a number of minor improvements to the circuit, a new PC board design and a shielded toroidal power transformer which has allowed us to eliminate the earlier design's regulated power supply which was housed in a separate box.

This month we present the first in a number of articles on the new amplifier module and a subsequent stereo class-A amplifier delivering 20 watts per channel. Ultimately, it will give far better sound quality than any valve amplifier and at a far lower price. Nor will its audio performance be degraded over a relatively short time by component ageing, as happens inevitably in any valve amplifier.

Leo Simpson

ALTRONICS ADVERTISING CORRECTION

Please note that on page 3 of the advertising flyer included with this issue, several items in the current "Altronics Price Cuts" promotion are advertised with incorrect prices. Under "Rack Shelf Discounts", the part numbers H 5352, H 5362, H 5353 and H 5363 are shown as "2 for". This is meant to read "2 up" – eg, H 5352 is $45 each when you buy two or more. Altronics apologises for any inconvenience caused.

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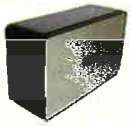

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This programmer connects to a USB port & has a 32 pin ZIF socket. It will program from 16k to 8M.
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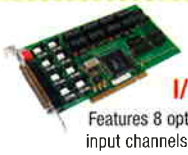

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MAILBAG

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CFL energy savings non-existent

With regard to your article on the proposed ban on incandescent lamps (April 2007), the purpose is to save energy, right? Maybe our politicians ought to take a step back and look at the bigger picture.

The cost of a product often relates reasonably well to the energy cost of mining and refining the raw material, manufacturing, packaging and transport. So a CFL might cost say 10 times the (energy) cost of an equivalent incandescent to supply to the customer.

I have quite a number of lamps in my house that are essential but are infrequently used and then only for very short periods of time. I've yet to see a 500W CFL flood lamp and would hate to think of the cost – yet my rear security light is just that and would operate for perhaps 90 seconds per year!

The point I am making is that putting CFLs in these locations will certainly result in a net whole-of-life energy loss. That is, the power station will have to produce more power to make and run these CFL lamps, over a lifetime, than the incandescents they replace. Obviously, this argument does not apply to high-use lamps and I support their application. But in my considerable experience, the life of CFLs can more typically be around the 300-2000 hour mark and this seriously impacts the energy benefits of their use. Perhaps the pollies need to employ engineers to add some logic and sense to their pontifications.

Ian Thompson,
Duncraig, WA.

23W energy saver lamp flashes at night

I would like to bring an interesting side effect of CFLs to your attention. I bought two 23-watt "Philips Tornado", "Compact High Light Output", "Energy Saver" light bulbs from Coles in Sydney. The packaging states that they "can operate within 170-250V range".

These bulbs are very bright (equivalent to 125W incandescent) and give off a fairly pleasant warm white light. The interesting (and slightly irritating) bit is that when mounted in a ceiling light and with the wall switch turned off, the lamp dimly flashes very briefly several times a minute, all night!

I tested each of the bulbs in various ceiling fittings, finding the flash rate varies slightly, depending on location. Neither bulb would flash in a lamp that breaks both Neutral and Active. I could not reproduce the effect in several other types of "energy saver" lamps that I have at hand.

The light circuit wiring and switch-

SILICON CHIP: the last of the Mohicans

Firstly, congratulations on the outcome of your first excellence awards, announced in the February 2007 issue. It is really hoped that this initiative continues to grow. Remember that if even one student is motivated you have succeeded.

Perhaps I could be described as a "magazine junkie", having started in my school days with Radio & Hobbies and moving on to such publications as Electronics World, Electronics Australia, ETI, CQ, QST, 73, Talking Electronics, Nuts and Volts, Practical Wireless, Amateur Radio and from its first issue, SILICON CHIP. No doubt you have visited a newsagency recently and have observed that you are just about the last of the Mohicans.

We all have pet theories as to the mechanisms driving the demise of some of these publications and I see the deliberate "dumbing down" of the country right at the top of my list. In the midst of all of this, SILICON CHIP has continued to go from strength to strength, so please take a pat on the back, as my perception is that it is serving a wider interest base.

In his comments on the publication of articles on valve amplifiers (Mailbag, page 9, February 2007), Ian Farquar is certainly on the wrong tram. In the world of hobby electronics, experimentation is a positive way forward and valve technology, albeit becoming obsolescent, is a valid hobby interest. While comparisons between valve and solid-state technology may be valuable, discussions as to which is "better" are meaningless.

Any "hands-on" experience gained through construction will provide educational benefits well beyond the use of commercially-built equipment or computer simulation.

It must be said that the current wave of TV advertisements promoting apprenticeships and encouraging students to turn to maths and science raise doubts in regard to the motivation behind them. With the anti-science campaign of recent years being so well organised and funded, and indeed being very successful, I wonder how it will be possible to put the knitting back together.

For example, how could a student cope with university level studies in maths and science-oriented subjects after passing through a school system where the teachers of these subjects are on the endangered species list?

George McLeod,
via email.

Playmaster AM/FM tuner morphed into mailbox

Almost the whole nation is awash with idiotic-sized tiny letterboxes which were designed for the needs of the 1920s. There must be millions of (A4-size) magazines which are subscribed to in Australia every year but when they arrive at the average home, we see the mail-person fold it in half and squeeze it (and any attached CD or DVD) through the tiny slot of the letterbox.

My personal solution to the problem is the new Playmaster Snailmail Inbox project. It is the perfect size for A4 magazines and is based on the Playmaster Stereo FM Tuner-Digital Clock project by Leo Simpson in the November & December 1978 and January 1979 issues of "Electronics Australia" magazine. I also plan to have a 150mm diameter newspaper tube suspended underneath it.

Michael Katalinic,
Lavington, NSW.

Comment: what sacrilege! Your old AM/FM tuner project should be venerated in a softly lit display case in your home rather than having to stand out in the elements and being force-fed junk mail. We are very sad at this sorry state of affairs.

Seriously, you are right. But rather than recycle defenceless tuners, there are millions of old computer cases which would be suitable for the job. Painted and adorned with a street number, they should last many years.

es in our house is old and possibly a bit leaky. The switch is definitely in the "Active" line. An old DMM shows either zero or 1-2V AC across the open circuit socket with the light switch off.

I assume that there must be some fairly efficient (non-leaky) electronics in the bulbs to produce this effect. The only device, to my knowledge, of similar efficiency is a neon indicator that has sufficiently high impedance to flicker in this sort of situation.

Lee Braithwaite,
via email.

Comment: we recently observed the flashing CFL effect ourselves in a number of lamp fittings. We have concluded that it is not a fault in the CFL or the 240VAC wiring but an artefact of the capacitance of the wiring to the light switch (from the ceiling junction box). In a typical home, this will be about six to eight metres of sheathed twin cable and this can be expected to have a capacitance of maybe 300pF or more.

In effect, this cable capacitance across the switch lets the CFL bridge rectifier build up sufficient DC to let the circuit fire the CFL tube, collapsing the DC and letting the cycle repeat ad infinitum. It is acting as a relaxation oscillator.

While you are aware of the flashing effect only at night, it happens all the time. If it worries you, it could be stopped by connecting a small capacitor across the CFL socket, say .01µF (10nF) 250VAC class X2. Alternatively, the effect could probably be stopped if the cable to the switch was changed to "twin and earth".

This leakage capacitance effect also occurs with incandescent lamps (and any other load for that matter) but it is of academic interest only.

GPS frequency reference is not optimum

I would have expected a more reliable design than that used for the GPS-Based Frequency Reference in the March 2007 issue. The method used to cascade counters IC4 & IC5 is incorrect.

The TC output of a 74HC160 synchronous counter is not guaranteed to be glitch-free and the following counter can increment on glitches in TC. The correct method would have been to cascade the two 74HC160s and the

Atmel's AVR, from JED in Australia

JED has designed a range of single board computers and modules as a way of using the AVR without SMT board design

The AVR570 module (above) is a way of using an ATmega128 CPU on a user base board without having to lay out the intricate, surface-mounted surrounds of the CPU, and then having to manufacture your board on an SMT robot line. Instead you simply layout a square for four 0.1" spaced socket strips and plug in our pre-tested module. The module has the crystal, resetter, AVR-ISP programming header (and an optional JTAG ICE pad), as well as programming signal switching. For a little extra, we load a DS1305 RTC, crystal and Li battery underneath, which uses SPI and port G.

See JED's www site for a datasheet.

AVR573 Single Board Computer

This board uses the AVR570 module and adds 20 An./Dig. inputs, 12 FET outputs, LCD/Kbd, 2xRS232, 1xRS485, 1-Wire, power reg. etc. See www.jedmicro.com.au/avr.htm

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Mailbag: continued

Still a place for valve technology

Recent Mailbag contributions have continued from a few folk who would like to see valves confined to the history books. I have the view that there is a place for this technology and that it should not be dismissed just because it is "old". My home contains a mix of digital electronics and solid state and valve amplification units, all of which live together in peace and harmony.

There is no doubt that there are plenty of readers who would be interested in seeing what your talented designers could come up with in terms of a valve amplifier. There is a plethora of solid-state amplifier designs and so a valve one would be something a bit different. EL34 and 6L6 valve types are commonly available, as is the 12AX7 for the preamp.

As a point of interest, I have noted that a number of high-end ($3000+) musical instrument amplifiers are "point to point" hand-wired and use tag strips rather than PC boards. And some even use a valve rectifier (5AR4).

The reality is that valves are not going to go away. The technology continues to occupy a valuable, important and respected position in high-end hifi and musical instrument amplification.

John Parker,
via email.

Comment: we have considered all the correspondence about valve amplifiers since the editorial on the subject in the November 2006 and concluded that relatively few people would actually build a state-of-the-art valve amplifier when confronted with the likely cost of well over a thousand dollars. Instead, we felt that far more people would build the class-A amplifier presented in this issue, as it will be easier to build, much lower in cost and have ultra-low distortion.

We can also guarantee that it will sound better than any valve amplifier.

following JK flipflop synchronously, by connecting the TC from IC4 to CEP of IC5, and connecting TC from IC5 to the JK inputs of both flipflops in IC6. IC4, IC5 & IC6 should then be clocked from the same 10MHz source.

The easiest fix to the circuit error is to connect pin 11 of IC4 to pin 11 of IC3e, connect pin 11 of IC5 to pins 14, 3, 7 & 10 of IC5 and connect pins 1 & 5 of IC6 to pin 2 of IC5.

The phase of the 50kHz signal relative to the 1MHz signal is unimportant so this fix will work well. The design will then work reliably over time and temperature even if different manufacturers' parts are substituted. Not all 74HC160s are equivalent in performance.

If instead of connecting the outputs of IC8 & IC9 to the 8-bit DAC register (IC12), the phase measurements had been filtered with a Kalman filter in the processor and then the resultant high resolution averaged data fed to the 8-bit DAC via a software dither generator to increase the effective DAC resolution, far higher accuracy and stability would have been achieved.

In fact the 4046 and associated dividers could have been eliminated by clocking IC8 + IC9 continuously by the 10MHz oscillator being disciplined and sampling the current count on the leading edge of the PPS signal. About 100ns RMS random jitter would need to be added to the PPS signal to ensure unbiased averaging of the phase samples. A synchroniser (8-bit shift register) would be used to synchronise the jittered PPS signal to the 10MHz oscillator being disciplined. A 74AC164 or equivalent performance device would be required to reduce the rate of synchroniser failure due to metastability to less than once in a few billion years. HCMOS is way too slow for a synchroniser.

The second 10MHz oscillator is thereby also eliminated. The short-term stability of the 10MHz oscillator could be significantly improved by using a relatively simple discrete bipolar oscillator rather than a noisy gate oscillator. It should then not be too difficult to achieve a short and long-term stability of better than a few parts in a billion.

Dr Bruce Griffiths,
Hamilton, NZ.

Comment: see the amended GPS-Based Frequency Reference circuit in this issue.

Dumped computers have intact records

Here are some ideas for recycling. When I buy a drum pack of CDs there are spacer washers included on each side of the stack to keep the CDs from self-destructing in transit. These are perfectly sized for hose to tap washers on your garden hose.

With the advent of reasonably priced "direct to CD" printers, the imagination runs wild on all the possible designs for clock faces that could be printed on a CD (at less than 30c). For $5 or less you can get a quartz clock movement from craft or $2 shops that fit extremely well in the hole of the CD. It makes a nice, original, useful, cheap gift.

CD-ROM drives can be used (with a redundant power supply) as a stand-alone CD player. The analog output is directly compatible with any consumer amplifier line RCA inputs, so all you need to do is make up a lead with the right plugs. However, when selecting a CD-ROM, check the front panel buttons and make sure it has a dedicated play/skip button in addition to the eject button, so it can be manually operated; some drives don't have this feature. Obviously, to keep it simple, there is no software control and it could be mounted in a box with an environmentally friendly off switch.

On a more serious note, computers from my local tip/recycling centre/waste management facility now include DDR P4s, in addition to the odd $10,000 industrial colour laser (HP8550DN, HP4500DN), mono lasers (HP4050DN by the score), plotters (HP650C, HP755CM) and photocopiers, sometimes with absolutely nothing wrong with them other than crash damage from being toppled out of a ute/truck.

However, my concern is the boxes that, for whatever reason, have become superfluous to present needs and end up on the heap. Some computers do have minor faults (maybe a dirty connection, blown video card, modem or power supply, or the RAM needs reseating) but they often come with the entire hard drive intact, just waiting to be removed and re-sited in my test rig for perusal.

I have come across computers from a government hospital with full patient records, from an accountant with everyone and their stuff that he's worked for since 1993, a solicitor with 36,000 individual clients, what they own, where it is, how much it's worth, etc, defence department machines with names & addresses of generals and other senior ranks, schools with personal child details, small businesses and all their affairs, plus aid agencies (both domestic and international).

I'm no wizard, so if I can access this then what do the dedicated detectives see when they go looking? By bringing this up I'm probably shooting myself in the foot and I'll have to start collecting garbage bags and food scraps 'cause there won't be any more hardware. But I will be able to sleep soundly knowing that I've done the altruistic bit this year. Any other readers got similar horror stories?

Name and address supplied but withheld at the writer's request.

Comment: you would think that any government department or business would at least security wipe any drives before dumping computers. Better still, they should pull out the drive and destroy it, to prevent data recovery.

Modern cars have too much performance

With respect to Julian Edgar's scathing article on fuel economy, etc of modern cars (SILICON CHIP, December 2006), I fully concur with everything he said but he should have said more.

In the mid 1970s when the fuel crisis had become reality, I remember an article quoting vehicle manufacturers' predictions whereby in the 1990s we would have cars that would achieve 3 litres/100km. This could be one of those false memories that some of us suffer from time to time but there is no doubt in my mind it could have been achieved.

Julian blames weight, which is a big factor. I blame the power-to-weight factor. Many modern cars would have been racing cars in the 1960s and 1970s. Recently, the Topgear TV show put two muscle cars from the 1960s, a Jaguar E-type & an Aston Martin DB4, against a Honda Accord Euro (2.4l). The Honda murdered the oldies in every test.

How much better would fuel economy now be if we stayed with the same performance levels as average cars of the 1970s?

John Taylor,
Donvale, Vic.

Ferocious Felines Fouling Flivver's Fine Paint Finish

In reference to your correspondent's problem with cats scratching the paint of his/her new car (Ask SILICON CHIP, February 2007), a friend has the same problem and solves it effectively by putting mothballs in a stocking and leaving the bag on the bonnet of his car. The cats soon got the message.

Keith Gooley,
Adelaide, SA.

Priority switching for CB radio

I am writing in response to the request by T. D. (Ask SILICON CHIP, March 2007) regarding a mixer for CB and/or mobile signals through his car sound system. This system was used in the 23-channel "Clarion JC-201E" CB radio, using the "RCJ-001" remote control head. This operated a relay to switch both stereo channels from the stereo system, the right channel being silenced and the CB output being fed to the left channel.

The remote head in this case also housed the channel selector but this had no role in the audio switching, the incoming audio providing the drive signal to the switching transistor to operate the relay. The audio was controlled by the "Squelch" control, hence only a user-selectable level of audio was applied to the system. This ensured reliable operation and avoiding undesired interference to the stereo sound.

Don Henriks,
Adelaide, SA.

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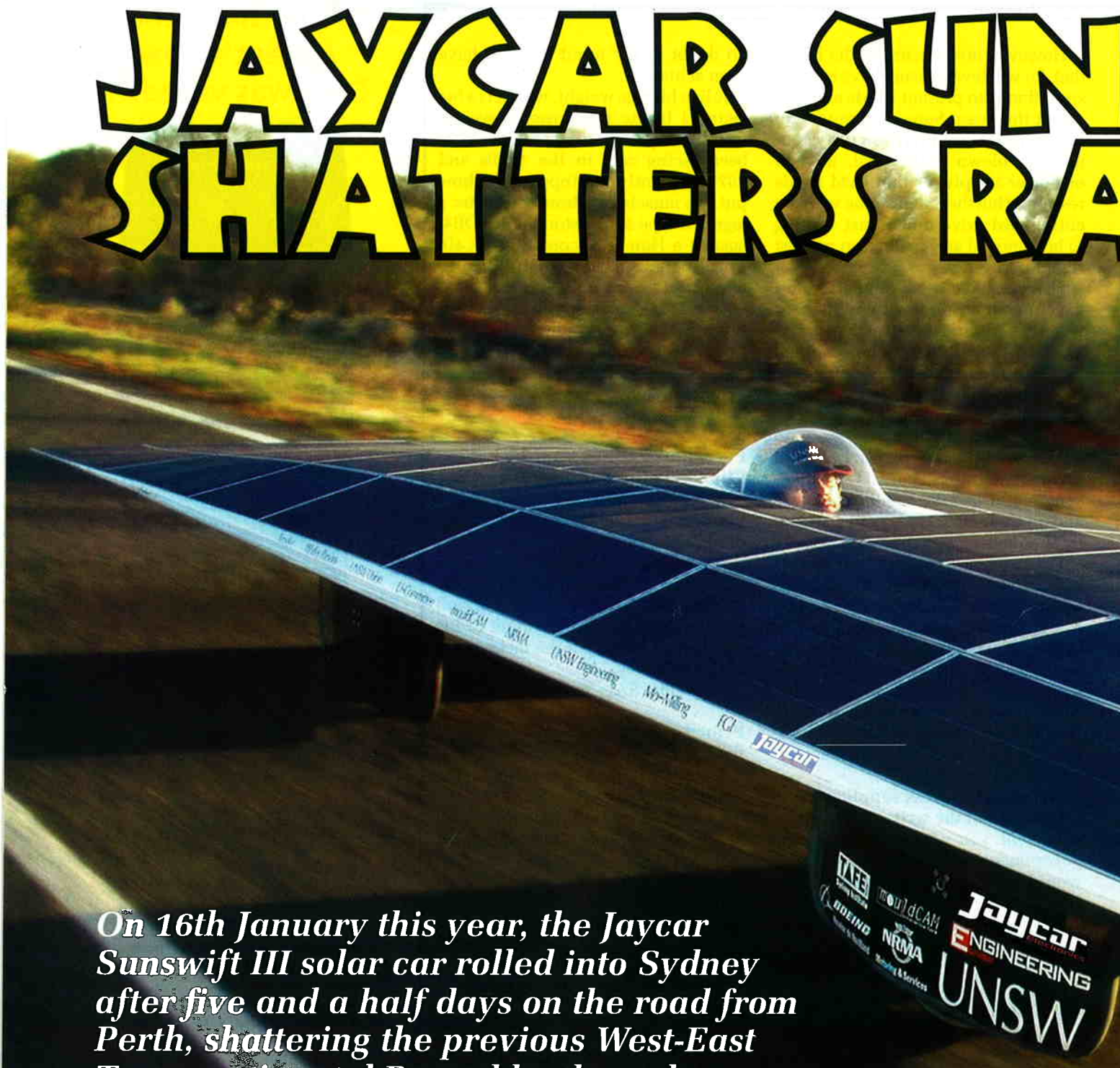


On 16th January this year, the Jaycar Sunswift III solar car rolled into Sydney after five and a half days on the road from Perth, shattering the previous West-East Transcontinental Record by three days. The UNSW Solar Racing Team is to be congratulated for their tremendous achievement.

SWIFT III
ACE RECORD

by LEO SIMPSON

Despite cloudy weather for the first two days of the record attempt the team was still able to push through for the fastest ever time. This record is unlikely to ever be bettered since the technical regulations have changed for the next solar car race, requiring the vehicles to be more like conventional cars.

The adventurer Hans Tholstrup did the original west-east Australian solar car trip in 1983, in his solar car, the Quiet Achiever.

Subsequently, in 1987, the World Solar Challenge invited bright young engineers and scientists from around the world to pursue the ideals of sustainable transport.

The ultimate challenge is to design and build a car capable of travelling across the Australian Continent on the power of sunlight and prove it by undertaking the 3000km journey in the spirit of friendly competition against others with the same goal. Over the last 20 years more than 300 solar car teams from around the globe have competed in the race from Darwin to Adelaide.

In effect, by breaking the West-East Transcontinental record, the Jaycar Sunswift has written the last chapter for solar race cars as we know them.

Why? Because this year's Panasonic World Solar Challenge will be run with more conventionally shaped cars, ending the reign of cars which are shaped like a credit card and not much thicker.

Jaycar Sunswift probably also marks the end of evolution of existing solar car electronics, although this remains to be seen.

Suffice to say, it is the end of development of cars measuring 6m x 2m and with driver lying supine in a mobile sauna.

Evolution has been the key word in solar car development over the last 20 years. Their overall design has changed relatively little while their overall efficiency has approached 100% but never quite got there – the classic asymptote.

It was time for a change.

Ultimately, Sunswift is a show-case of the best in solar car technology, as this story demonstrate s.

Dave Snowdon, from the University of NSW, designed the electrical system in Sunswift III over the last five years or so. The major components are the motor, motor controller, solar array, maximum power point trackers, batteries and telemetry/control system.

If you're looking for comfort in the drive from Perth to Sydney, we're betting that the Jaycar Sunswift III is not the best way to go. But what fantastic fuel economy: 0l/100km!

Pancake motor

The car's motor is built into one of the rear wheels in order to save the losses in a transmission if it were used. The downside of that is more rapid tyre wear in the driven wheel but the extra weight of dual wheel drive was thereby avoided. The motor itself is approximately 98% efficient.

The electrical design of the motor was produced by the CSIRO for the Aurora solar car. It is essentially a brushless AC motor with a central stator (containing the windings) and an outer rotor (containing the magnets). In effect, it is like an inside/out synchronous motor and long-time tape recording enthusiasts would recognise this as being similar in construction to a Papst motor.

The differences are many. For a start, the motor is very thin, allowing it to fit inside a thin wheel hub and streamlined fairing, for minimum wind resistance.

The mechanical design of the motor was done by a thesis student and involved significant analysis. There is roughly 6kN force between the two rings of magnets when the mo-

Here's the Jaycar Sunswift III, tailed by support vehicles, on Sydney's M5 motorway, nearing the end of its epic journey. They didn't tell us if they had to pay the toll . . .

And speaking of support vehicles, here's the inside of one. It has both voice and telemetry contact with the solar car by radio, GPS and (just in view at left) laptop diagnostics

siliconchip.com.au

Back in the workshop at UNSW, Simon Li, now Electrical Team Leader, shows us the driver's position. It's almost supine, with just the head poking up through the solar cell "lid" into the clear head guard. The two joysticks (one in each hand) control the vehicle's direction and speed.

tor is assembled but the motor casing must also take all the cornering loads, etc.

Motor controller

The motor controller fills the normal role of the commutator. Three Hall Effect sensors allow it to sense the position of the magnets relative to the windings and then switch the motor currents accordingly. The controller was designed by Tritium Pty Ltd, who originally worked on the University of Queensland's Sunshark solar car project. The UNSW team worked closely with Tritium while they were developing the controller and added a CAN interface and other improvements.

The controller is about 99% efficient. It consists of three Mosfet half bridges (one for each phase of the motor) and a Digital Signal Processor. (Readers wanting to understand bridge motor drive should refer to the DC Speed Control article elsewhere in this issue).

The motor controller pulse width modulates the bottom Mosfets in the half bridges in order to regulate the motor current and to control the speed. The motor controller also provides regenerative braking (ie, turning the motor into a generator, to charge the batteries while slowing the car down) by switching the phases in the appropriate order. The motor controller can handle up to 100A through the phases at up to 170V DC.

The motor controller outputs a square wave (ie, the phases are either on or off, directly dependent on the state of the Hall Effect sensors. This causes a small efficiency loss, since the current is always at the same high value for a given torque. A newer version of the controller will produce a sinewave output which will have a higher peak but lower RMS current, for the same torque, giving better efficiency.

Interestingly, those very high currents caused severe problems with motor over-heating when climbing long hills at low speeds. The high currents are partly a result of the "coreless" construction of the motor, meaning that it generates very little back-EMF at low speeds. So in spite the motor being rated at up to 98% efficient, at low speeds

Again back at UNSW, Yael Augarten (one of the Sunswift's drivers) shows the inside of the driver's "cabin". The full racing harness is essential, just in case a large gust manages to cause loss of control.

it is nowhere near that efficient and dissipates considerable heat as a result. This problem was exacerbated by the very poor ventilation inside the motor hub and wheel fairing – streamlining has a definite downside here.

Solar array

Sunswift III's solar array is made up of 1034 Sunpower A-300 solar cells. These are back-side contact cells, which means the electrical contacts don't shade the front of the cell. Their efficiency is between 20 and 21%. The cells have been laser-cut to be rectangular so that they can be packed tighter into the solar array. They were encapsulated into thin, flexible panels by Hans Gochermann.

Electrically, the solar array is organised into six panels consisting of more than 100 cells wired in series. This

Working on the inside-wheel motor. There is only one wheel driven to save weight, albeit at the expense of tyre wear. The motor is up to 98% efficient.

Unlike most cars, hoisting the bonnet simply means taking the solar-panel "lid" completely off.

Taking it off is not difficult, as this photo shows. Four people can easily lift it – it's unwieldy rather than heavy.

is necessary for several reasons, the main one being cell matching. A solar cell is only able to pass as much current as the light falling onto it will allow. Even if two identical cells are wired in series, if one is receiving less light than the other, the optimum current will be close to the optimum current for the cell receiving the least light. This is particularly important in a curved array, where cells which point in the same direction will receive about the same amount of light.

The UNSW team did thorough simulations of the car over the course of the World Solar Challenge (from Darwin to Adelaide) to work out which parts of the car received the same amount of light for most of the day and secondly, where the best cells should be placed (since there is a spread in efficiency, even within the same type of solar cell).

Maximum power point tracker

The other consideration when designing the solar array electrically was the Maximum Power Point Tracker (MPPT) voltage. The closer the solar array voltage to the battery pack voltage, the higher the efficiency of the MPPT. The solar cells have an open-circuit voltage of approximately 0.65V and a maximum power voltage of approximately 0.55V.

Solar cells have a non-linear current-voltage (IV) curve. That means that the solar cells will operate best at a particular voltage. The position and shape of the curves changes dramatically with changing light conditions. By contrast, the battery voltage varies according to its state of charge. Therefore to get the maximum output from the solar array, separate MPPTs are connected to each solar panel. The MPPT is a boost converter which attempts to find the solar panel's maximum power voltage (Vmp) and perform a voltage conversion from that voltage to the battery voltage.

The MPPTs for the Sunswift are partly home-grown and partly outsourced. The power section was manufactured by the University in Biel, Switzerland, who sell MPPTs to other solar car teams. The control section is home-grown, based around a microcontroller and an FPGA (Field Programmable Gate Array). The FPGA is required to generate the relatively complex timing signals required by the power section. The power section uses a soft-switching boost converter. "Soft switching" means that there is both zero voltage and zero current across and through the transistors when they switch. Two Mosfets are required for this topology and a third is required for synchronous rectification. As a result, the boost converter is up to 99% efficient.

Believe it or not, this three-line alphanumeric display is the only instrumentation the driver can see. As well as current, voltage, power for the array, battery and motor, it shows speed and motor temperature.

The driver does have rear vision, courtesy of the video camera mounted behind his/her head and an LCD mounted inside the vehicle. This photo also shows two battery packs and some of the control equipment.

The control section measures the input current and voltage and output voltage. It runs an inner control loop to maintain a given voltage on the solar panel (since the voltage doesn't change nearly as much with changing light conditions), and an outer current loop to adjust that voltage in order to find the maximum power point. It can adjust it by one of several algorithms. The two most well-known algorithms are "perturb and observe"(for hill-climbing) and "fixed-percentage" which periodically stops the tracker, measures the open-circuit voltage and takes a fixed percentage of that to be an estimate of Vmp).

The control section also connects to the car's CAN network for telemetry.

Batteries and microcontrollers

Sunswift's batteries consist of 200 prismatic lithium-polymer cells. These are wired into modules of five in parallel, and 40 of the modules are wired in series to give a complete battery pack. This gives a pack which is right on the World Solar Challenge's 30kg limit. At 4.1V per cell, the battery pack can be charged to 164V and discharged to 2.7V per cell (108V) when absolutely flat. The pack has a capacity 40Ah and can drive the car approximately 300km at 100km/h.

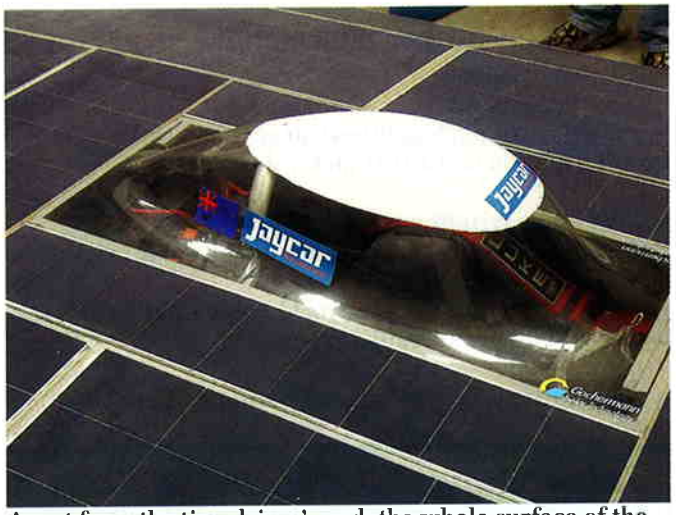
The batteries are connected to a custom-designed battery monitoring system. The battery monitoring system is built into the same PC boards which form the interconnection between the cells. Each PC board has a microcontroller which monitors four of the series modules. There 10 microcontrollers which communicate with a master via an isolated serial bus. The microcontrollers themselves are powered via linear regulators from the batteries they are measuring. The battery monitoring system is important because the cells are not necessarily identical and therefore do not charge and discharge the same way. Cells can become out of balance at different states of charge.

CAN and telemetry

The car's telemetry and control system consists of a telemetry network and a control bus. The control bus is a dedicated link between the driver controls and the motor controller, and is a simple serial RS485 bus. The telemetry uses a CAN network, consisting of a large number of microcontroller-based nodes spread throughout the car. These nodes have dedicated jobs such as controlling the front indicators, measuring the battery/array/motor current and interfacing with the battery monitoring system. A CAN network links all these nodes, the MPPTs and the motor controller.

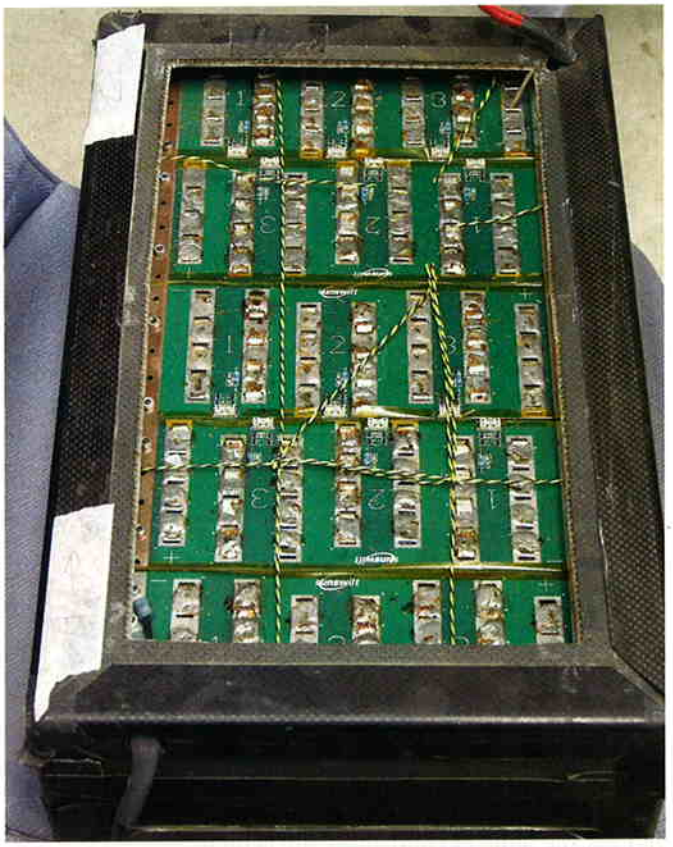
All the data off the network, is sent in packet form by wireless ethernet to the support car. The support car can also send messages back to the telemetry network for con-

The guys assured us they were not being (overly!) sexist with "Yael's First Drive" trophy . . . they admitted that just about all novice drivers manage to damage tyres while they get the hang of controlling the vehicle.

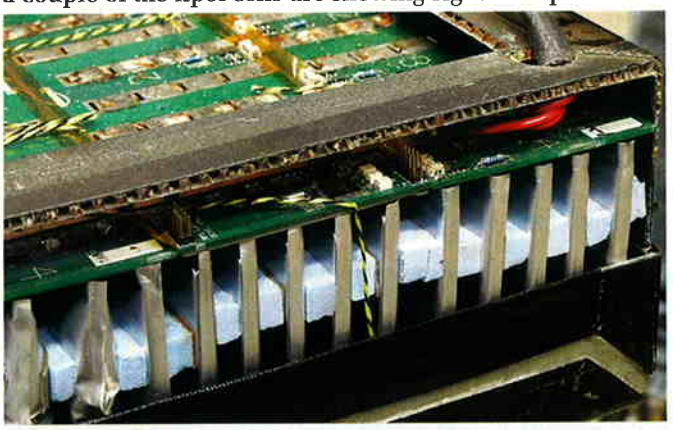


Apart from the tiny driver's pod, the whole surface of the vehicle is covered with solar panels. They are specially made to be able to fix to curved surfaces and in total are worth approximately $150,000

The low-profile and extremely low resistance Michelin radial tyres were made specifically for the solar racers but are now unfortunately not available. The team is now looking for alternative tyres.



Here's a close-up of one of the battery boxes. Every cell is individually monitored to ensure that maximum power is available from each one. Some of the connecting buses are shown in the photo below (the side of the above photo) and a couple of the lipol cells are showing signs of expansion.



trol, configuration and maintenance purposes.

The entire network is isolated, giving the system fault tolerance. The whole system is decentralised, meaning that if one node fails, the rest of the system should continue to operate.

Some of the most interesting CAN nodes in the car are follows:

Negative sum – forms the negative star-point of the battery, motor and array. It measures the current from each into the star-point using isolated Hall Effect sensors. It also measures the battery pack voltage and integrates the currents to give amp-hours. This forms the basis of battery state of charge estimation.

GPS – measures the car's position, altitude, etc. This allows the support car to do a look-up in the course database in order to know exactly how far the car has gone and needs to go. This is essential for race strategy.

Tilt sensor – measures the car's angle up/down relative to horizontal. This allows the strategy software to calculate how much power the car would be using on a flat road, and fit a model so that it is possible to a) work out whether the car is using more or less power than it should and b) what speed the car should be run at in order to reach the destination (the course survey also gives the gradient and overall rise).

One-wire temperature sensors – controls a network of 1-wire temperature sensors on the solar array.

MPPT - sends out panel current and voltage, as well as several diagnostic values such as heatsink temperature and ambient temperature. Is configurable via the network (can change the tracking algorithm, perform an IV sweep, etc).

Motor controller - sends out lots of data. The main values are the car's speed, motor current, input current (which is also measured in the negative sum), motor temperature, motor controller temperature, low-voltage bus voltage, etc. The motor controller can also be controlled via the network, including modification of the cruise-control set point.

Driver display - a 40x2 character LCD panel allows the driver to read what is going on, including speed. The driver also tries to maintain limits on the motor currents in order to avoid overheating and loss in efficiency. Furthermore, should the wireless link fail, the driver can communicate information displayed on the driver display back to the support vehicle via CB radio.

Left-hand-side controls - while the driver's right-hand-side controls interface directly with the motor controller via RS485, the left hand side controls interface with the CAN network and controls the indicators, hazards, horn, etc.

There are also other miscellaneous electronic devices in the car, including the rear vision display and camera and CB radio.

In summary, while the photos in this article show that Sunswift is not much different mechanically speaking, from many earlier World Solar Challenge vehicles, its overall electronics and electric design is fiendishly complex.

What will the new solar race vehicles bring? SC

Websites for further information:

www.sunswift.com

www.tip.csiro.au/Machines/success/sc.html for information on CSIRO motor design.

www.chuck-wright.com/SolarSprintPV/SolarSprintPV.html for information on solar cells

www.wsc.org.au/2007 for World Solar Challenge technical and event regulations

www.tritium.com.au/ for information on motor controllers

Acknowledgement: Our thanks to David Snowdon, Yael Augarten and other members of the UNSW Solar Racing Team for their assistance in the preparation of this article.

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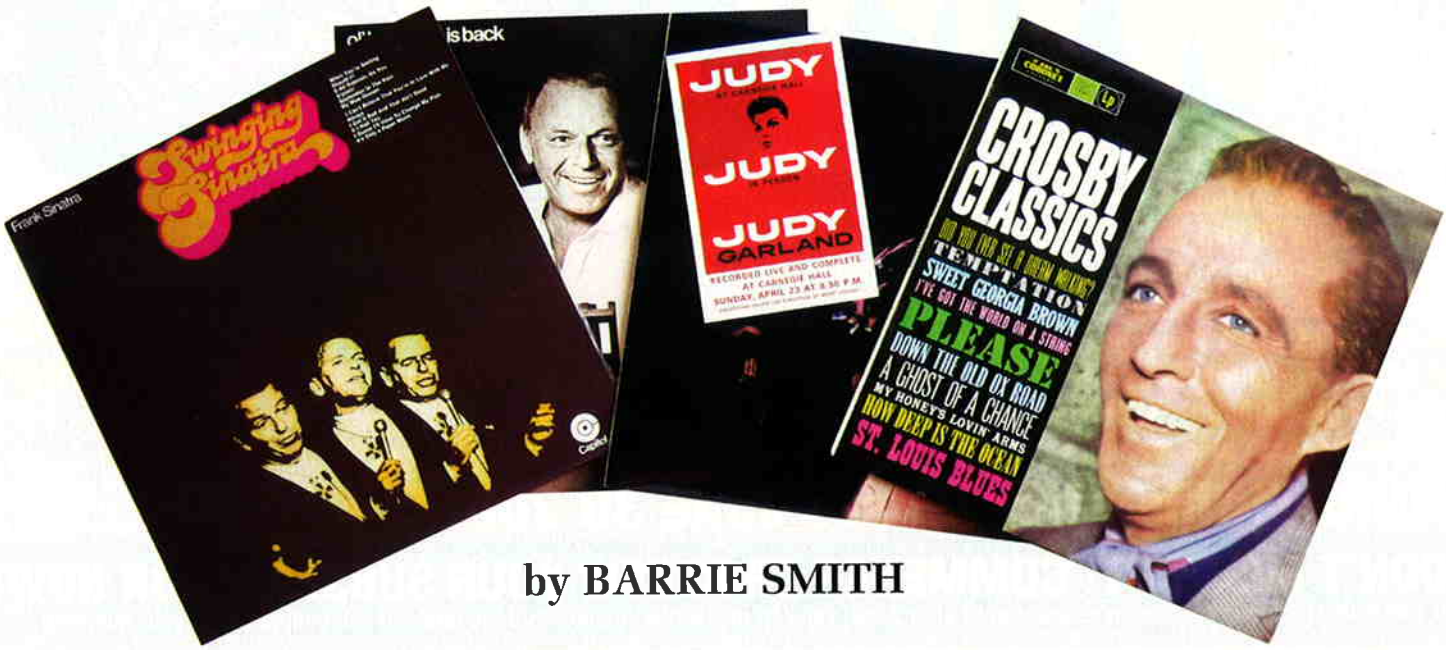
GIVE 'EM A

Not too many (any?) hifi systems these days come with a record turntable. So what do you do with that collection that's been gathering dust since your old faithful died? There's plenty of turntables out there! Just dip into our listing.



by BARRIE SMITH

If you had any doubts about the future of LP recordings just walk around your local hifi store and see the bins full of LP reissues and even some new titles. And they're not cheap either, with prices frequently level with and sometimes above new CDs.

Maybe you want to wrap your tone arm around the Buddy Holly LP, "pressed on 180 grams of virgin vinyl, remastered from the original tapes without compression!" Just $48 for a singe disc.

Of course, the happy hunting grounds for vinyl platters with a bit of age on them are the charity shops, garage sales and school/church fetes.

Plenty of people these days are spending the odd hour or spare day converting their vinyl to CD or MPS tracks for use in iPods and similar. With the right software you can bring analog recordings back to original quality: no clicks, bumps, pops.

You need a turntable. There are a few options: you may have no desire to mix it with eBay to grab a preloved turntable from a seller that probably matches the age of your LP collection. If you're in need of some turntables or other components of a 'certain age' you will be surprised at how easy and economical they are to acquire these days. Aside from checking around with friends (especially the spouses or partners thereof!) to prise some unwanted hardware from their hesitant fingers, the next stop should be the used section of hifi retailers. But you may find the occasional absence of manuals with used equipment a bit of a bind!

I regularly haunt Len Wallis' premises in Sydney; the pre-owned amps, turntables and tape machines are a joy to behold, in excellent working order and very fairly priced. Other cities have similar businesses you can scour.

But if you prefer not to mess with gear of an indeterminate age and go the new route, there is a virtual forest of new models out there from prestige manufacturers, as well as the majors like Sony and Panasonic.

New turntables can vary enormously in price, comparable in the range from a second hand Datsun 120Y to a new Merc 200; I'm talking in a range from $400 to $68,000!

This turntable listing includes units priced below $2000.

There are others ... but if you're spending in the tens of thousands of dollars for a turntable to retrieve the sonic glories of yesterday you either need your head read — or you should get out more!

(BTW: the abbreviation MM in the listing stands for moving magnet cartridge.)

SPIN!

Buying a turntable

The argument continues: is the reproduction of sound from an analog LP superior to that from a digital CD?

I'm not buying into it other than to say I *personally* don't miss the clicks and bumps from a vinyl LP and I do find the quality on the best of CDs far superior to that of top LPs. So there.

But if you want to copy your LP collection to CD and you've dumped the family record player years ago there is no alternative: you will be buying a new or second hand turntable.

Basic turntable construction is just that: pretty basic. In the main case there is **a motor**, a **drive system** which connects the motor to the platter so that it rotates at the appropriate speed and usually (though not always) some method of selecting that speed.

Alongside the platter (which itself rotates the records) is a **tone arm** which moves over the surface of the record. It carries the **cartridge** which converts into electrical signals the miniscule movement of the **stylus** as it tracks the record's groove and vibrates from side to side in accordance with what was recorded in that groove.

There is usually some method of adjusting the downward force the stylus exerts on the record.

The best turntable systems can reduce the clicks and other noise from the record surface while inferior turntables may well exacerbate this.

Speeds

33-1/3 RPM (revolutions per minute), 45 RPM and the lesser seen (older) 78 RPM are the main ones you will encounter. Let's hope you're not confronted by 16-2/3 RPM discs; many older turntables do not handle th is speed!

Before investing in a turntable, check to see if your amplifier or receiver has "phono" inputs.

These are inputs with (a) the appropriate sensitivity (usually around 5-10mV); (b) the appropriate input impedance (around 50kΩ) and (c) most importantly, response tailored to reverse the equalisation which is applied to records in the manufacturing stage.

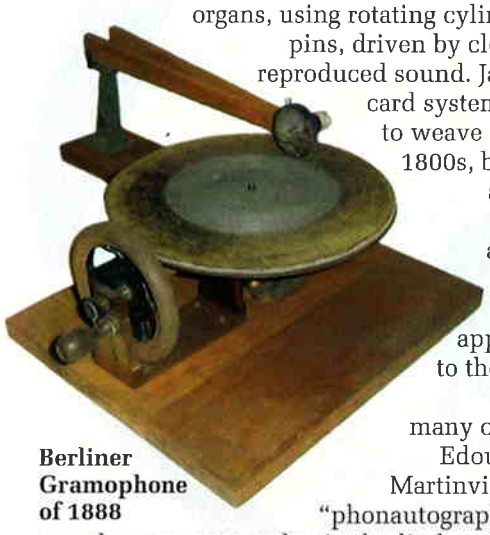
If your amplifier or receiver doesn't have such an input, you will have to buy a turntable with inbuilt preamp or buy/build a separate preamp to connect between the turntable and your amp/receiver. The output from such a preamp (or preamp-equipped turntable) can be fed directly into the sound input of your computer for dubbing onto the final CD. Many computers only have "mic" inputs – use this in the absence of a "line in" input and reduce the gain.

Recorded Sound Progress

A successful and commercially viable method of recording and reproducing sound was long in coming but it was not until 1948 and the arrival of the 12 inch 33-1/3 RPM vinyl LP that music quality began to approach that of the original performance.

The earliest recorded sound system dates back to circa 1500 BC. The mammoth "vocal" statue of Memnon at Thebes had the ability to make the sound of a harp string every day.

The early 16th century saw the appearance of barrel organs, using rotating cylinders and attached pins, driven by clockwork gears that reproduced sound. Jacquard's punched card system, initially devised to weave fabrics in the early 1800s, became the basis of an organ driven by bellows, pumping air jets through the card holes to create music. The approach was similar to the player piano and paper rolls that many of us grew up with.



Berliner Gramophone of 1888

Edouard-Leon Scott de Martinville in Paris made a "phonautograph" in 1857 to trace sound waves onto a carbonised cylinder with a stylus attached to a diaphragm that vibrated from spoken sounds. The device did not record the sound, only a graphical image of sound.

In 1877 Charles Cros described a phonograph device but never built a model. Edison was seeking to improve the telephone in 1877 when he discovered the recording device known as the phonograph. In the same year Edison recorded a human voice speaking "Mary had a little lamb" onto the first phonograph using a tinfoil cylinder. Playing time was about 2-3 minutes. Early materials used for the cylinders were lead and wax.

The Graphophone (as distinct from Gramophone) was patented in 1885, using wax-coated cylinders incised with vertical-cut grooves.

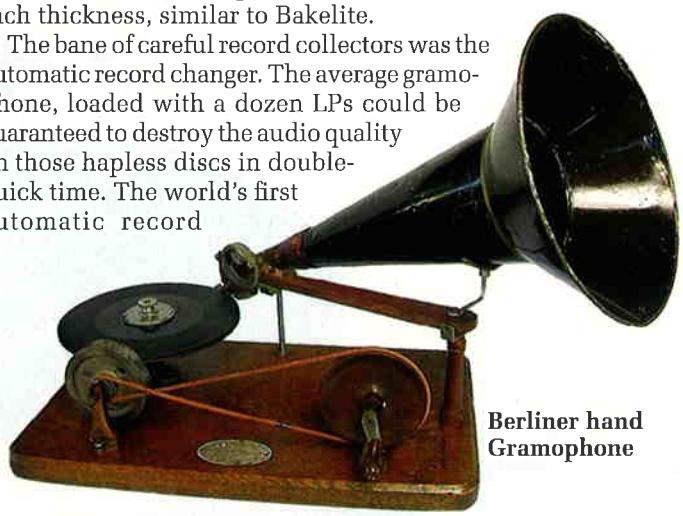
Emil Berliner was first with a phonograph — the gramophone — in 1887 that used a flat disc, a non-wax disc engraved with a lateral-cut groove. The 7-inch (17.5cm) disc was hand-cranked at 30 RPM with a two minute playing time. Berliner was the first to mass-produce hard rubber vulcanite copies from a zinc master disc. He later used shellac, which was used later in pressing the popular 78 RPM records that were displaced by vinyl LPs only in 1948. The early steel styluses tracked at a weight of nine ounces (255 grams).

Magnetic recorders came along in 1898, patented by Valdemar Poulsen using steel wire. Wire recorders were still in use by Australian radio stations in the 1950s.

Double-sided flat discs were first sold in the early 1900s. HMV marketed a complete opera on 40 single-sided discs. The Odeon company competed with the Nutcracker Suite on four double-sided discs.

Edison fought back in 1912 with blue celluloid cylinders that played for four minutes. Played with a diamond stylus, the new cylinder had low surface noise that gave better quality than flat discs of the period. However Thomas Alva finally conceded victory to the flat disc and began to use discs with a surface of plastic, laminated to a 1/4 inch thickness, similar to Bakelite.

The bane of careful record collectors was the automatic record changer. The average gramophone, loaded with a dozen LPs could be guaranteed to destroy the audio quality on those hapless discs in double-quick time. The world's first automatic record changer was invented by Tasmanian Eric Waterworth, who showed it first at the 1927 Sydney Home Show. Due to a series of events Waterworth did not profit from the device, the patents lapsed and a number of English companies manufactured record-changing gramophones with almost all of them using the stepped centre spindle — a central feature of Waterworth's design (information from SPAT).



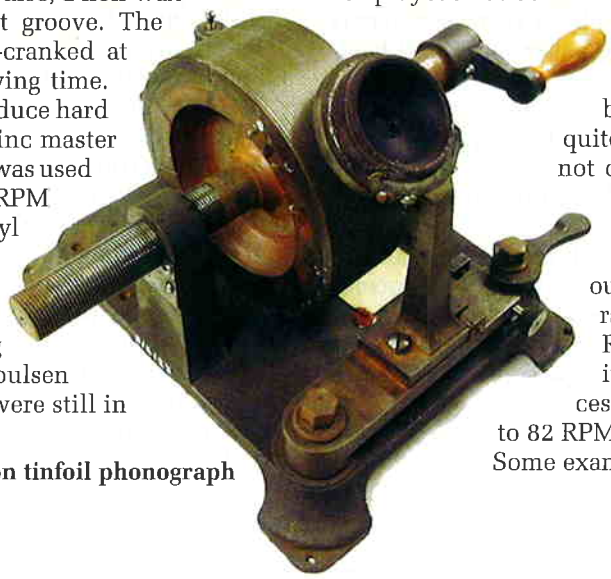
Berliner hand Gramophone

Vinyl discs were first used in 1929 when RCA began making transcription discs from optical movie soundtracks for radio stations to play on air. The same year saw the final production run of Ed ison cylinders and discs.

In 1930, RCA Victor launched the first commercially-available vinyl long-playing record, marketed as "Program Transcription" discs. These revolutionary discs were designed for playback at 33 RPM and pressed on a 30cm-diameter flexible plastic disc

Many 78s were not recorded at exactly 78 RPM: speeds of between 72 and 85 RPM were quite common. A standard speed was not decided upon until around 1930. Up until then, record and replay speeds were pretty much subject to the left to the fancy of the various record companies; in fact, speeds ranged anywhere from 60 to 130 RPM. The majority of records, as it worked out, played quite successfully at speeds that ran from 72 to 82 RPM.

Some examples: Edison and Diamond Discs



Edison tinfoil phonograph

LEN WALLIS AUDIO

THE HI – FI HEAD LINES

Any technology which not only continues to exist a quarter of a century after it has been 'superseded', but which, in some markets, now outsells the product that superseded it must have a lot going for it.* When CD was released in Australia in 1983 it was expected to spell the death of the turntable – despite protests by specialty retailers and audiophiles that the humble LP still sounded considerably more musical than CD. Almost 25 years later and turntables continue to sell, and continue to find new markets among a younger music loving audience.

Also fascinating is that there are still new turntable companies starting up. One such company is US based Music Hall, marketing a small range of quality, yet well priced, turntables originating from Europe. Even the baby of the range, the MMF 2.1 selling for $599, sounds delightful. Music Hall has released six models in all, the most expensive selling for $2,995. All turntables come complete with appropriate cartridges, which is part of their value. Music Hall has had the foresight to match each tonearm with a cartridge that is not only relevant in terms of quality, but cartridges that work well with these arms. Much of the quality of any turntable is the marriage of the arm and cartridge – marrying a good quality cartridge to a good quality arm does not necessary give the desired result.

There is also a continuing market for higher quality turntables, and here we fall back on a very old and well respected manufacturer out of the UK. Michell have been producing turntables for decades. Many will recall

the futuristic turntable used in the movie A Clockwork Orange – a forerunner of the current Michell range. While the design may have toned down a little, they are still visually unique. Like many high quality turntables, not only is the choice of cartridge left up to the individual, but so is choice of tonearm. At Len Wallis Audio we carry both the GryoDec SE ($2,899) and the Orbe SE ($6,699).

The continuing interest in vinyl has led to a market in quality stand-alone phono pre-amplifiers. This has happened for two reasons. Firstly, many amplifiers today have deleted the phono stage in their amplifiers, which means that in order to play your vinyl you will need an outboard device. Secondly, it is obvious that those embracing vinyl today are interested in quality of performance, and there can be no doubt that many of today's amplifiers that do incorporate a basic phono stage are using the cheapest available. We now carry outboard phono stages from QED, NAD, Musical Fidelity, Perreaux and Black Box.

- It has been reported that for the first time in history, turntables outsold CD players in the UK last year.

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play at 80 RPM. Early Pathé discs run at 100 RPM. It was rare that a '78 RPM' record actually played at a true 78 RPM.

All of these will track happily at 4-5 grams, the optimum weight given the groove-wall geometry/dynamics of the 78.

Columbia Graphophone

The first magnetic tape recorder was built in Germany by Dr. Fritz Pfleumer and AEG/Telefunken in 1931; BASF/AEG made the tape. This recorder was publicly demonstrated in Berlin in 1935. This invention became the foundation of the US Ampex corporation (see Ampex and Germany).

Ampex got a leg up thanks to an enterprising US engineer and the end of WW2. (See AMPEX and Germany).

1948: Columbia introduced the first 12-inch 33-1/3 RPM micro-groove LP vinyl record with 23 minutes per side capacity. Tracking weights of 5-8 grams were common.

1949: RCA Victor introduced the 7 inch 45 RPM micro-groove "Extended Play" vinylite record and player.

1953: Elvis Presley made his first recording on disc at the Sun Studio of Sam Phillips in Memphis; the second recording by Elvis at Sun a year later was taped on two Ampex 350 recorders.

1956: the Chrysler Imperial 16-2/3 RPM record player with 7-inch ultra microgroove records appeared.

1958: world standard for stereo records established and first stereo LPs sold.

1963: Philips demonstrated its first compact audio cassette using high quality BASF polyester 1/8 inch tape that ran at 1-7/8 inches/second.

1966: US cars were equipped with 8-track stereo cartridge tape players made by the Lear Jet Corporation.

1969: Dolby Noise Reduction introduced.

1971: quadraphonic records were announced, recording four separate sound signals. This was achieved on the two stereo channels by electronic matrixing, where the additional channels were combined into the main signal.

1982: first digital audio 12.5cm CD discs marketed by Sony and Philips. The maximum playing time would be 74 minutes, long enough to hold Beethoven's 9th Symphony.

1987: Digital Audio Tape (DAT) players introduced. It was recently announced that production of DAT recorders is to end.

1999: Sony and Philips launch Super Audio CDs (SACD) delivering two channel stereo and (optionally) a 5.1 channel surround mix.

2000: DVD-Audio discs appeared, offering reproduction of up to 7.1 channels.

2001: Apple's iPod, using a minuscule internal hard drive, is on the market.

RCA Victor Phonograph

Early Gramophone

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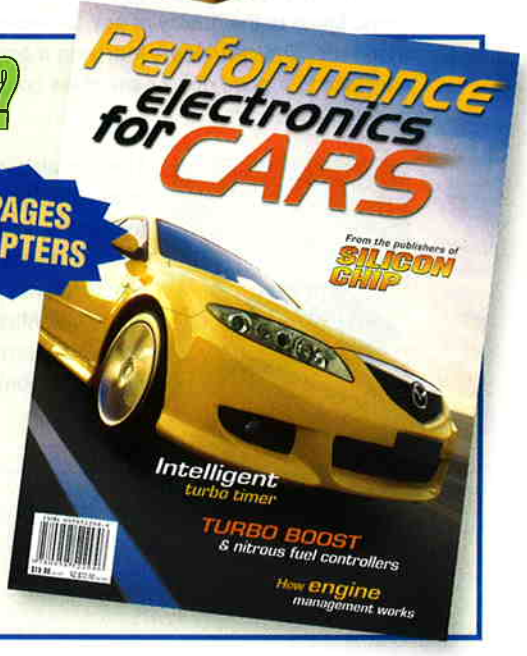
- Build test instruments to check fuel injector duty cycle, fuel mixture and brake and coolant temperatures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This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

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And speaking of the war years, R & H had some of the best propaganda imaginable! Even if you're just an electronics dabbler, there's something here to interest you.

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Finding that Stylus

If you're searching for turntable spares — cartridges, styli, etc — one source is Decibel Hifi at www.decibelhifi.com.au.

Another is Soundring. They stock a wide range of record player needles, styli and turntable needles, all delivered straight to your door. They have online database of over 118 top brands and models, so you're sure to find the replacement needle or cartridge you are looking for.

Some of the brands include Audio Technica, Denon, Dual, HMV styli, JVC, Nivico, Ortofon.

Replacement needles and other hifi accessories: Marantz, National-Panasonic-Technics, NEC, Ortofon, Philips, Pioneer, Sansui, Sanyo, Sharp, Shure, Sony, Stanton, Toshiba, Yamaha and many more.

Go to www.soundring.com.au/record-play

For much of this surprising activity in turntables and their essential spares you can thank the DJs that are jazzing the young at discos and cafes around the country.

One company who is very-DJ aware is Spank Records (www.spankrecords.com.au) who not only sell turntables from many well known companies but also deal in headphones, cartridges and styli from Ortofon, Shure, Stanton and others.

For cartridges/styli and a heap more, Amber Electronics (www.amberelectronics.com) is a good one-stop shop. The cartridge brands include Leda, Io, Europa and The Tribute. Amber's 'heap more' covers preamps and integrated amplifiers.

The Turntable Listing:

Denon DP-29F
33-1/3, 45 RPM, DC servo motor, belt drive, phono equaliser, tone arm and MM cartridge.
Price: $299

Denon DP-300F
33-1/3, 45 RPM, DC servo motor, fully auto, belt drive with MM cartridge and built in preamp.
Price: $699

Dual CS415-2
33-1/3, 45 RPM, DC servo motor, belt drive, tone arm and MM cartridge.
Price: $499.

Dual CS-435-1
33-1/3, 45 RPM, DC servo motor, belt drive, tone arm and MM cartridge.
Price: $649.

Dual CS-455-1M
33-1/3, 45, 78 RPM, DC servo motor, belt drive, tone arm and MM cartridge.
Price: $799.

Goldring GR1.2
33-1/3, 45 RPM, DC servo motor, belt drive, tone arm and MM cartridge.
Price: $699.

Goldring GR2
33-1/3, 45 RPM, DC servo motor, belt drive, tone arm and MM cartridge.
Price: $1199.

Outputs

Note: most turntables in this listing have outputs only for preamps; these are of insufficient level and of no help when copying LPs to your computer.

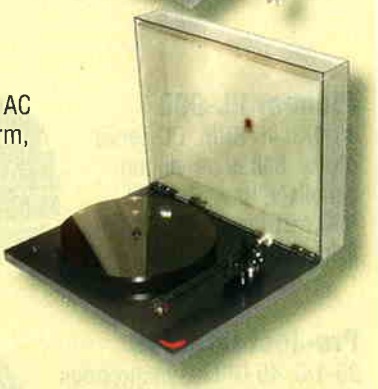
There are some turntables that have an inbuilt pre-amp and line level outputs; these can be connected directly to your computer for dubbing to the hard drive.

There are also a couple of budget-priced turntables on sale in mainstream retailers. K-Mart has two models, one of which has an inbuilt pre-amp. Prices are $49 and $69.

There is also the Optimus LAB1100 turntable and pre-amplifier combo from Dick Smith Electronics. At $98 it's certainly priced right.

Also of note are two Stanton models that have a digital output.

Moth ALAM01
33-1/3, 45 RPM, synchronous AC servo motor, belt drive, tone arm, no cartridge.
Price: $715.



Moth ALAMOX
33-1/3, 45 RPM, synchronous AC servo motor, belt drive, tone arm, no cartridge.
Price: $935.

NAD C555
33-1/3, 45 RPM, AC motor, belt drive, tone arm and MM cartridge.
Price: $799.

Optimus LAB1100
33-1/3, 45 RPM, DC servo motor, belt drive, inbuilt pre-amp, tone arm and MM cartridge.
Price: $98.

Panasonic Technics SL-BD20
33-1/3, 45 RPM, DC servo motor, belt drive, tone arm and MM cartridge.
Price: $279.

Vinyl spoken here!

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Brands include Linn, Origin Live, Pro-Ject, Rek-O-Kut, Rega, Graham Slee Projects, The Cartridge Man, The Disc Doctor, Garrott, Ortofon, Audio Technica, Moth, Loricraft.

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Copyright

Copyright, especially in Australia, can be a legal minefield.

Take a look at www.copyright.org.au and see if the situation worries you enough to deter you from copying your old analog material – in fact, copying *any* material.

In the US the copyright laws permit the making of one copy of an original for personal use. In Australia *no such provision exists*. Here it is illegal to make any type of copy of recorded music without the permission of the copyright owner – and that permission is rarely, if ever, given – especially without paying some form of licence fee.

The key points:

- There is **no** general right for individuals to copy recorded music, even from a record or CD you own and even if you want to use it on another form of "player" (eg, copying to an MP3 player or, as we are discussing here, copying old records to CDs).
- There is no general right to copy copyright material for personal use under Australian law.
- Ownership of a physical item (such as a CD) does not give you the right to make copies (including copying into a digital or other format).
- There is no general right to copy recorded music from the internet without the copyright owners' permission.

The reality is that thousands of people make copies of records and CDs for personal use every day of the year.

In moral and legal terms, it would be foolish to make copies for resale – or for gift-giving to another person.

Much more information awaits at www.copyright.org.au/PDF/InfoSheets/G070.pdf

Turntable with USB output

An easier approach could be the ION ITT USB Turntable, the world's first USB turntable. It allows you to convert a vinyl collection directly to CD or (even MP3) with the included recording software. It is a 'must have' for people who don't want to deal with clumsy adapters or mismatched audio formats.

The ION USB turntable includes Audacity software for Win/Mac for recording as well as a trial of Bias Soundsoap 2 for cleaning and restoring LPs.

If you've got a stack of old 45s, 33s or even 78s, you can now convert them to digital with this belt drive turntable.

As well as the USB output it has a line level output for connecting to any home stereo with CD or auxiliary (AUX) inputs, via the stereo RCA outputs; it also has a 3.5mm stereo input so you can take a feed from a stereo cassette machine. It is compatible with any software that supports USB audio input sound cards so you can convert your vinyl into WAV, WMV, AIFF and MP3s.

Includes a USB cable and pre-mounted cartridge with stylus and adjustable anti-skating control; a 45 RPM disc adaptor is in the kit. The turntable weighs 6 kg.

While the turntable has only 33-1/3 and 45 RM speeds the included software can be used to convert 33-1/3 RPM transfers to 78 RPM. Another trick: replay 33-1/3 RPM discs at 45 RP for the dub: whilst saving time, these speed conversions possibly compromises the quality. In the case of the 78 RPM trick, the LP stylus is certainly the wrong profile for the old 78 shellac grooves.

System requirements: Windows 98, 2000, or XP; Mac running OS9 or greater including Mac Universal.

Price: $349.00

1300 761 466

Panasonic Technics SL-1200MK2 and SL-1210MK2
33-1/3, 45 RPM, brushless DC servo motor, quartz direct drive, manual turntable.
Price: $999.

Panasonic Technics SL-1210M5G
33-1/3, 45 RPM, brushless DC servo motor, quartz direct drive, manual turntable.
Price: $1299.

Panasonic Technics SL-1200MK5 and SL-1210MK5
33-1/3, 45 RPM, brushless DC servo motor, quartz direct drive, manual turntable.
Price: $1099.

Pioneer PL-990
33-1/3, 45 RPM, DC servo motor, belt drive, phono equaliser, tone arm and MM cartridge.
Price: $349.

Pro-Ject Debut III
33-1/3, 45 RPM, synchronous AC motor, belt drive, tone arm and MM cartridge.
Price: $399.

Pro-Ject Debut III Phono SB
33-1/3, 45, 78 RPM, synchronous AC motor, electronic speed control, belt drive, preamp, tone arm and MM cartridge.
Price: $599.

Pro-Ject Xpression MK II
33-1/3, 45 RPM, suspended synchronous AC motor, electronic speed control, belt drive, tone arm.
Price: $599.

Pro-Ject RPM5
33-1/3, 45 RPM, synchronous AC motor, belt drive, tone arm.
Price: $849.

Pro-Ject RPM 6.1 SB
33-1/3, 45, RPM, synchronous AC motor, electronic speed control, belt drive, tone arm.
Price: $1199.

Pro-Ject RPM 9
33-1/3, 45 RPM, separate synchronous AC motor, perimeter belt drive, electronic speed control, tone arm.
Price $1999.

Rega P1
RB100 tone arm and Ortofon OM53 moving magnet cartridge.
Price: $599.

Rega P2
RB250 tonearm, stabilised 22mm platter, high quality main bearing,
Price: $799.

Rek-O-Kut Rondine Jnr
33-1/3, 45. 78 RPM with pitch control, belt drive, tone arm, MM phono cartridge with LP and 78 styli. Price: $594

Rek-O-Kut Vintage
33-1/3, 45. 78 RPM with pitch control, belt drive, tone arm, auto-return.
Price: $770.

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Nominal Voltage *	12V	12V *24V available on request	12V
Nominal Power	25W	50W	65W
Nominal Current	2.1A	4.2A	5.4A
Fuel consumption	1.1 litres per kWh. 1.3 litres per 100Ah		
Weight	7.3kg	7.5kg	7.6kg
Dimensions	(L x W x H) 435mm x 200mm x 276mm		
Batteries	40 to 200AH recommended		

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- **Theft Proof**
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Cleaning

Possibly the most critical factor in getting the best out of early analog recordings – especially disc, to a lesser degree tape – is getting rid of the cause of a lot of the noise and other garbage from the record surface: dust.

And that means cleaning both the media and the machines that play them.

In the heyday of vinyl records, no self-respecting audiophile would put a disc on the turntable without ensuring both were clean: the turntable platter with a dust brush and the disc itself with one of a variety of dust collectors designed for the purpose. Such things are still available today but you may have to search for them!

For really dirty recordings, by all means use appropriate methods to clean vinyls and tapes but watch out for shellac or acetate records – alcohol will destroy these – so use water-based compounds.

First of all, clean the mat of your turntable.

If a "78" is cracked at the edges, avoid wetting it with anything: some 78s have a centre of fibrous material which expands when wet and shatters the record.

Vinyls can be safely cleaned with distilled water, although grime will possibly be removed only by the use of proprietary fluids.

A whole list of excellent cleaning approaches can be accessed at Decibel Hi Fi (www.decibelhifi.com.au).

Or you can go to www.screensound.gov.au and follow the "Preservation" link.

Rek-O-Kut CVS14
Fully manual 33/45/78 RPM turntable with a continuously variable and calibrated "78" range of from 62 to 94 RPM, high-torque direct-drive motor, tone arm, can play up to 14-inch records.
Price: $990.

Rek-O-Kut CVS16
Fully manual 33/45/78 RPM turntable with a continuously variable and calibrated "78" range of from 62 to 94 RPM, high-torque direct-drive motor, tone arm, can play up to 16-inch records.
Price: $1210.

Rek-O-Kut Rondine 3
33-1/3, 45, 78 RPM, and 9 other speeds for vintage discs and half speed mastering, DC motor, belt drive, electronic power supply, Delrin platter, audiophile quality tone arm.
Price: $1980.

Sony PSLX250H
33-1/3, 45 RPM, DC servo motor, belt drive, inbuilt pre-amp, MM cartridge.
Price: $299.

Stanton STR8.150
33-1/3, 45, 78 RPM, DC servo motor, direct drive, inbuilt pre-amp, digital output, tone arm and MM cartridge.
Price: $1,099.

Stanton T.120
33-1/3, 45, 78 RPM, DC servo motor, direct drive, inbuilt preamp, digital output, tone arm and MM cartridge.
Price: $949.

Stanton T.80
33-1/3, 45, 78 RPM, DC servo motor, direct drive, inbuilt pre-amp, tone arm and MM cartridge.
Price: $699.

Stanton T.60
33-1/3, 45 RPM, DC servo motor, direct drive, inbuilt pre-amp, tone arm and MM cartridge.
Price: $399.

Thorens TD-170
33-1/3, 45, 78 RPM, DC servo motor, belt drive, tone arm and Ortofon OMB10 MM cartridge, fully automatic.
Price: $649.

Thorens TD-170 Phono
33-1/3, 45, 78 RPM, DC servo motor, belt drive, tone arm and MM cartridge and phono stage, fully automatic.
Price: $725.

Thorens TD-190
33-1/3, 45, 78 RPM, DC servo motor, belt drive, tone arm and Ortofon OMB10 MM cartridge, heavier platter, fully automatic.
Price: $799.

Thorens TD-240
33-1/3, 45, 78 RPM, DC servo motor, belt drive, tone arm and Audio Technica AT95E MM cartridge, fully automatic.
Price: $995.

Thorens TD-295 MKIV
33-1/3, 45, DC servo motor, belt drive, rigid tone arm and Audio Technica AT95E MM cartridge, heavier platter and plinth.
Price: $1149.

NEXT MONTH: We'll look at some of the software available to assist you in cleaning up old records and review one outstanding package!

ELECTRONICS SUPERMAN WANTED

OK, let's not be sexist.
Electronic Superwomen may also apply.

SILICON CHIP, Australia's only electronics magazine for the professional, technician and hobbyist, is looking for an experienced electronics all-rounder to join the editorial team.

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- A much-better-than-average writing ability.
- A much-better-than-average knowledge of electronics, technology, computers et al . . .
- Most importantly, the ability to marry the two of these criteria – ie, write about electronics, technology, computers and so on in language that is both easy-to-read and easy-to-understand!

The following would be well regarded:

- Experience in the real world of technology.
- Intimate knowledge of computers/computer operation/networking/applications/etc.
- Web page design and construction.
- Magazine/publishing experience (inc sub-editing).

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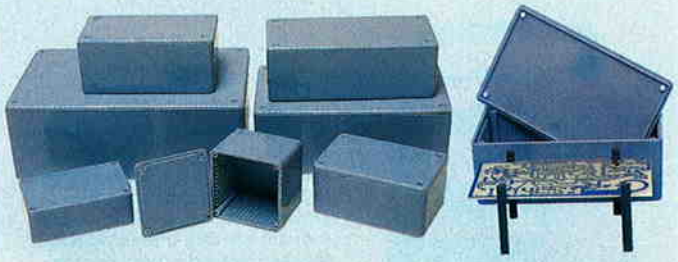

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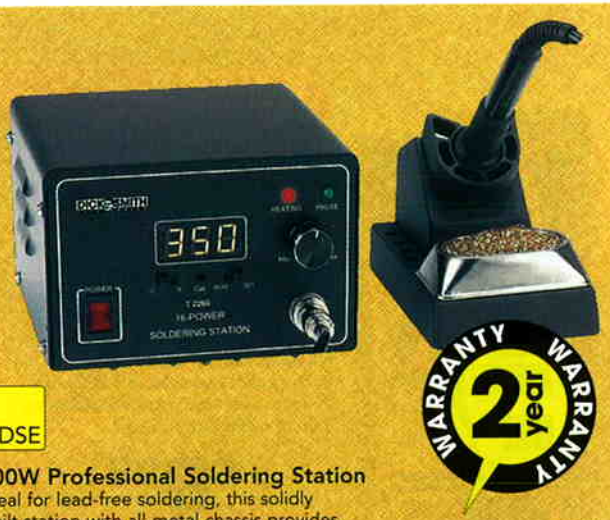

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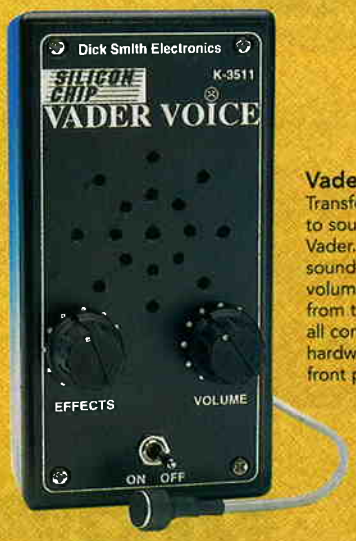

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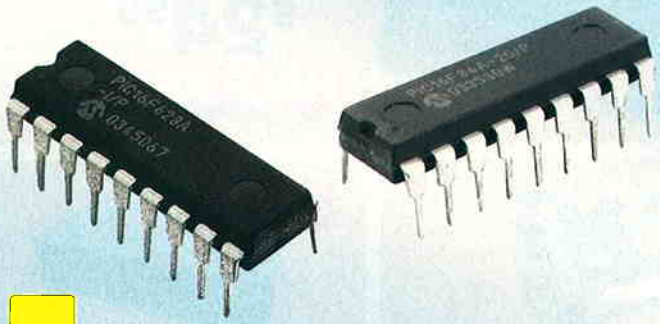

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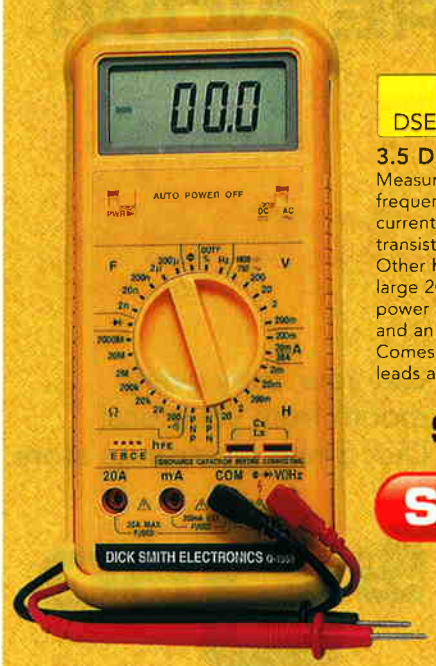

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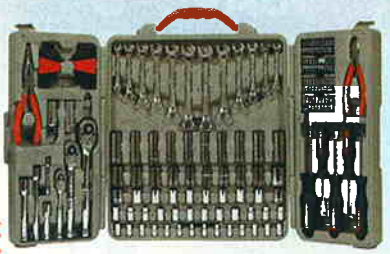

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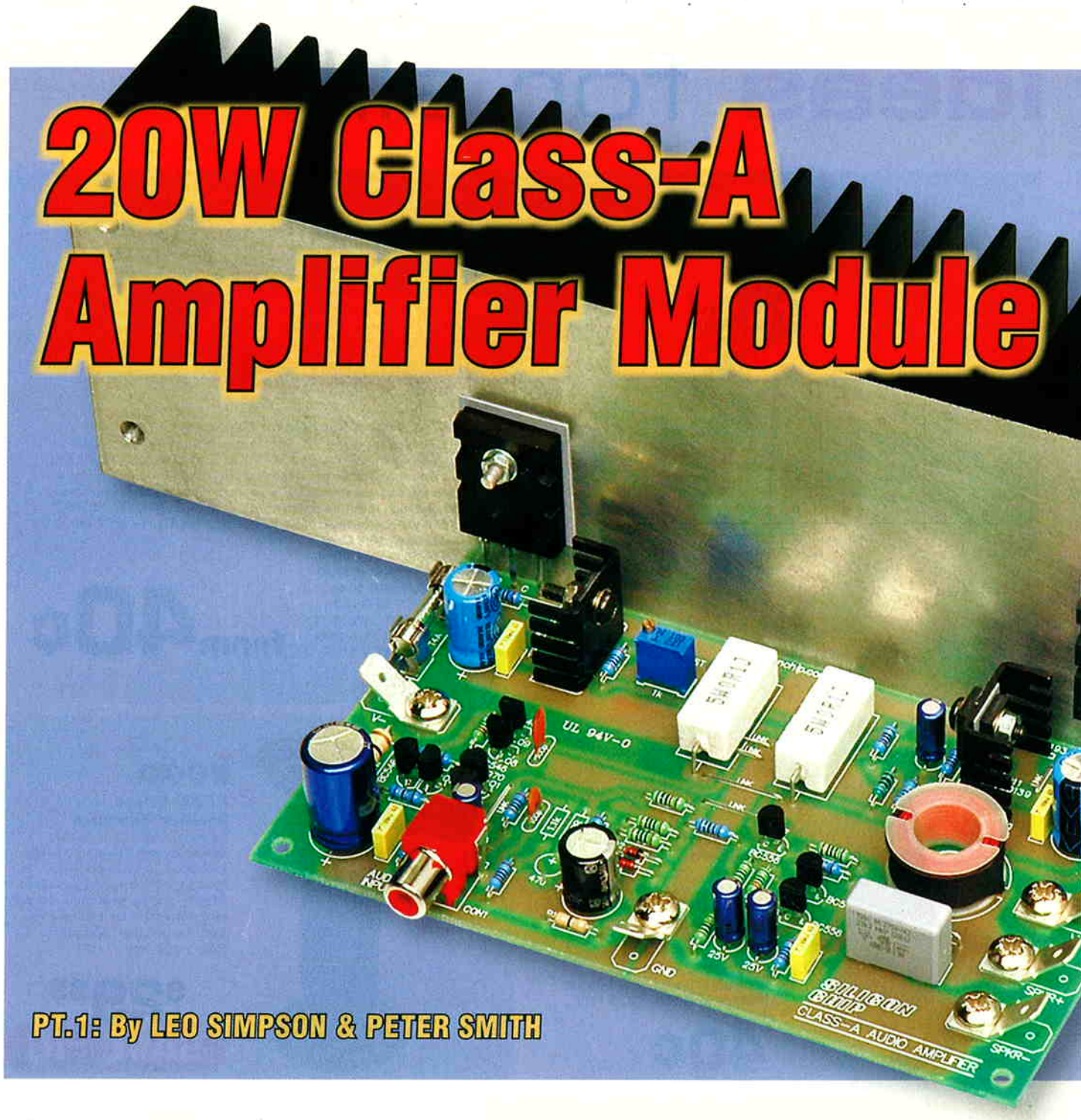
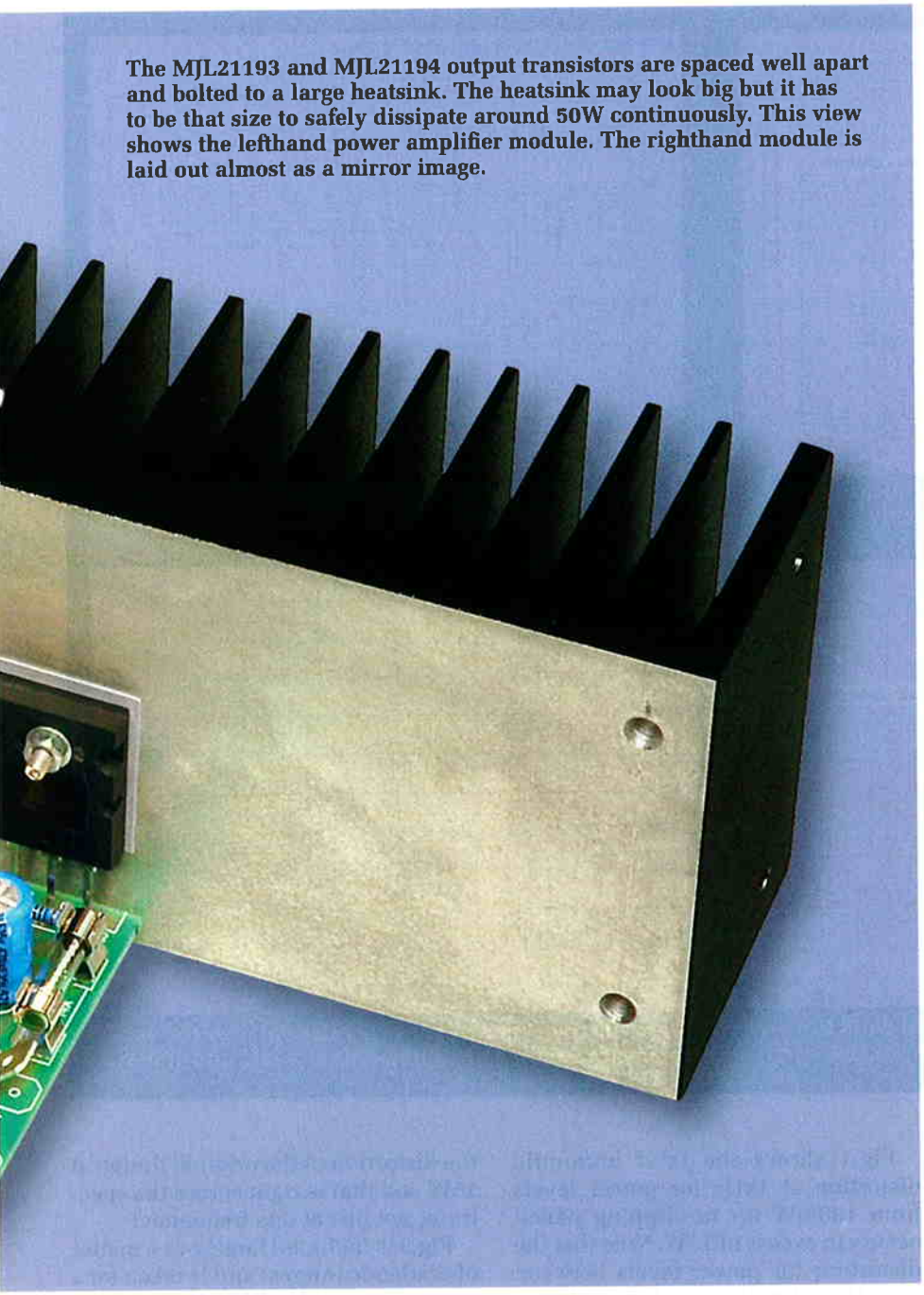
20W Class-A Amplifier Module



PT.1: By LEO SIMPSON & PETER SMITH

This new 20W class-A is a refinement of our very popular 15W class-A module published in July & August 1998. It features ultra-low distortion levels, very low noise levels and a greatly simplified power supply which improves overall efficiency. Since it runs in pure class-A mode, there is no crossover distortion at all.



The MJL21193 and MJL21194 output transistors are spaced well apart and bolted to a large heatsink. The heatsink may look big but it has to be that size to safely dissipate around 50W continuously. This view shows the lefthand power amplifier module. The righthand module is laid out almost as a mirror image.

THIS UPGRADED CLASS-A amplifier has been a long time coming. Virtually since the original circuit was published in July 1998, readers have been hankering for more power. Until recently, we have resisted because we knew that increasing the power output would bring a proportional increase in overall power consumption which was already quite high.

This is the great drawback of any class-A design. While they are beautifully distortion-free, they dissipate the same high power whether they are delivering a milliwatt, one watt or full power. And the total power consumption, and therefore heat dissipation, of the previous 15W/Channel Class-A Stereo Amplifier was 100 watts. That's quite a lot of power dissipation for not very much audio output.

So how could we increase the power output while staying within the original parameters – ie, the original large single-sided heatsinks and the 160VA toroidal power transformer? The answer was not simple but essentially involved analysing the weaknesses of the original design to see if we could make worthwhile improvements.

In the result, we have made quite a few minor improvements to the original amplifier module. Together, these added up to an overall major improvement which enabled us to dispense with the regulated power supply. This makes the overall circuit more efficient and means that the amplifier can now use some of the power previously wasted in the regulated supply. That also reduces component cost and actually helps reduce distortion in an already exceptional design.

Some of the changes in the design are based on ideas and circuits published by the noted audio designer Douglas Self and outlined in a number of his books (available from the SILICON CHIP Bookshop).

All in the same case

The 15W/Channel Stereo Class-A amplifier presented in August 1998 also featured a separate power supply box because hum radiation from the power transformer was quite high. This new design will feature a shielded toroidal transformer which means that there is no need for a separate box. We will talk more about this aspect in a future article.

Redesigned PC board

We have completely re-designed the PC board so that the two power output transistors are spread much further apart. Instead of concentrating the heat in the centre of the heatsink, it spreads the heat over a wider area and makes more efficient use of the available heatsink area. In fact, while the new amplifier module can deliver up to 25W (instead of the original 15W), the heatsink temperature remains about the same as the original design; ie, about 30°C above ambient.

By the way, we must stipulate that even though the amplifier can deliver up to 25W at the onset of clipping, it only provides pure class-A operation up to 20W. Beyond this, it is operating class AB – still with very low distortion but not genuine class-A.

We made this compromise to reduce the temperature rise on the heatsinks. With sufficient quiescent current to ensure class-A operation up to 25W, the heatsinks simply became too hot.

In fact, the new circuit is actually slightly more "voltage-efficient" than the old one, so that the available output voltage from the balanced supply rails is greater than before. We will see just

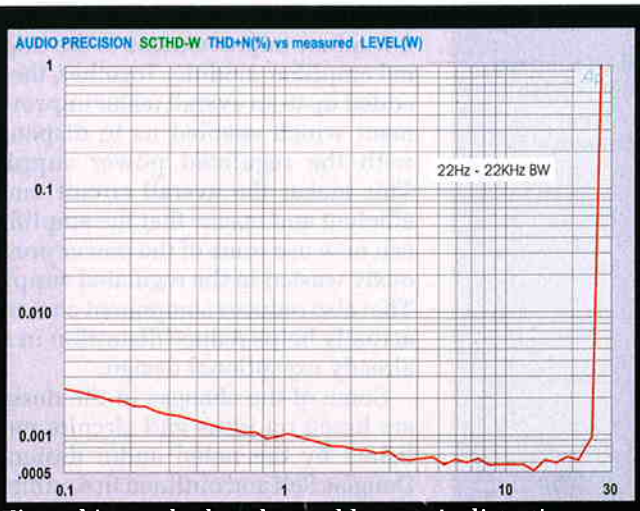


Fig.1: this graph plots the total harmonic distortion (THD) at 1kHz from 100mW to just over 25W.

Fig.2: the distortion versus frequency at 10W & 20W into an 8-ohm load (measurement bandwidth 22Hz to 80kHz).

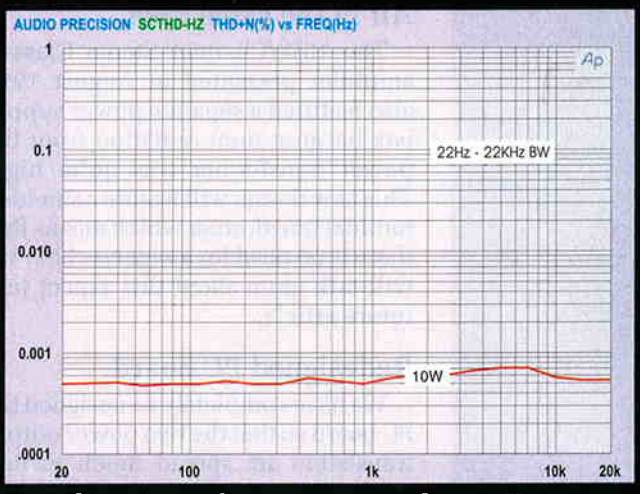


Fig.3: distortion vs frequency at 10W from 20Hz to 20kHz (measurement bandwidth 22Hz to 22kHz).

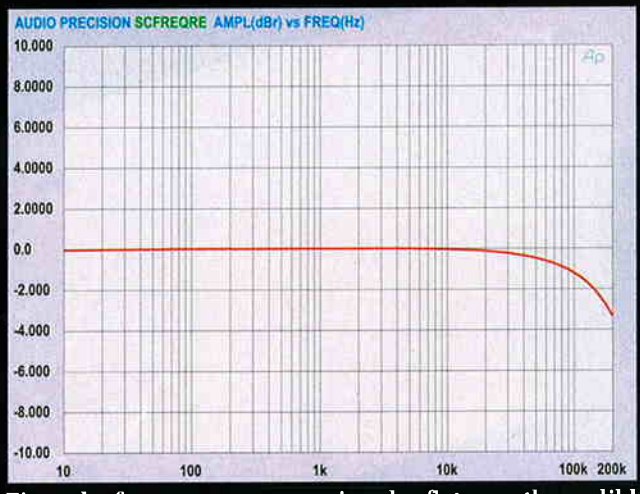


Fig.4: the frequency response is ruler flat over the audible frequency range, with -3dB points at 1.5Hz and 190kHz.

how these improvements have come about as we go through the circuit description.

Performance

Since many readers will not be familiar with the original design published in July & August 1998, we will present the complete circuit description and mention the differences with the older design where appropriate. But first, let's talk about performance.

The distortion of this new design is actually lower than the original, amazing though that may seem. For those who have the original articles and who want to make direct comparisons, we have produced equivalent distortion plots. If you don't have the original articles, you will just have to take our word for it that the distortion is lower.

Fig.1 shows the total harmonic distortion at 1kHz for power levels from 100mW up to clipping which occurs in excess of 25W. Note that the distortion for power levels between say 5W and 20W is far below .001% and is typically less than .0006% at around 10W.

Similarly, Fig.2 shows the distortion versus frequency for power levels of 10W and 20W into an 8-ohm load, using a measurement bandwidth of 22Hz to 80kHz. This is a far more stringent test as the distortion for any amplifier, even quite good designs, usually rises quite markedly at high powers for frequencies above 5kHz. But for this design, at 10W, the distortion at 20kHz is only marginally above that at 1kHz and is considerably better across the whole spectrum than the older design. At 20W, the new design has about half the distortion of the original design at 15W and that is right across the spectrum, not just at one frequency!

Fig.3 is included largely as a matter of academic interest and is taken for a power output of 10W for frequencies from 20Hz to 20kHz but with a bandwidth of 22Hz to 22kHz. Note that this means that harmonics above 22kHz will be ignored and therefore the distortion for signal frequencies above 10kHz will be artificially attenuated. Having said that, the distortion levels shown on Fig.3 are less than half that for the equivalent distortion plot (also Fig.3) in the July 1998 article.

Frequency response is ruler flat, as shown in Fig.4. It is -1dB at 90Hz and -3dB at 1.5Hz and 190kHz. This is a much wider frequency response than the original design and comes about because we have used much gentler

Parts List

1 PC board coded 01105071 ("left") or 01105072 ("right"), 146mm x 80mm
2 Micro-U TO-220 heatsinks (Altronics H-0630, Jaycar HH-8502)
3 TO-126 heatsink pads (Altronics H-7230)
2 TO-3P heatsink pads (Farnell 936-753 recommended, see text in Pt.2)
1 diecast heatsink, 300 x 75 x 49mm (W x H x D) (Altronics H-0545)
1 PC-mount RCA socket
2 M3 x 10mm tapped spacers
2 M3 x 6mm pan head screws
2 M3 x 10mm pan head screw
2 M3 x 20mm pan head screws
6 M3 flat washers
4 M3 nuts
5 M4 x 10mm screws
5 M4 flat washers
5 M4 shakeproof washers
5 M4 nuts
5 6.3mm single-ended chassis-mount spade lugs (Jaycar PT-4910)
4 M205 fuse clips (F1 & F2)
2 3A M205 slow-blow fuses
1 11.8mm or 13.8mm ID bobbin (Altronics L-5305)
1 2-metre length of 1mm-diameter enamelled copper wire
0.7mm diameter tinned copper wire for links
1 1kΩ 25-turn trimpot (Altronics R-2376A, Jaycar RT-4644)

Semiconductors

2 2SA970 low-noise PNP transistors (Q1 & Q2) (available from **www.futurlec.com**)
4 BC546 NPN transistors (Q3, Q4, Q8 & Q9)
3 BC556 PNP transistors (Q5- Q7)
2 BD139 NPN transistors (Q10 & Q11) (Farnell 955-6052)
1 BD140 PNP transistor (Q13) (Farnell 955-6060)
1 MJL21193 PNP transistor (Q12) (Jaycar ZT-2227, Farnell 955-5781)
1 MJL21194 NPN transistor (Q14) (Jaycar ZT-2228, Farnell 955-5790)
2 1N4148 diodes (D1, D2)

Capacitors

1 1000µF 35V PC electrolytic
2 470µF 35V PC electrolytic
4 47µF 25V PC electrolytic
1 220µF 25V PC electrolytic
1 820pF 50V ceramic disc
1 100pF 50V NPO ceramic disc (Jaycar RC-5324)
4 100nF metallised polyester (MKT)
1 150nF 250VAC metallised polyester or polypropylene (Farnell 121-5452)

Resistors (0.25W, 1%)

1 1MΩ	1 510Ω
4 10kΩ	1 270Ω
3 2.2kΩ	8 100Ω
1 1kΩ	3 68Ω
1 680Ω	1 16Ω

1 6.8Ω 1W 5%
1 10Ω 1W 5%
2 0.1Ω 5W 5% wirewound
2 1.5Ω 5W 5% wirewound (for testing)

Power Supply

1 PC board coded 01105073, 134mm x 63mm
1 16V+16V 160VA magnetically shielded toroidal transformer (see text in Pt.2). Must include 15V+15V auxiliary windings to power preamp module, if used.
4 M3 x 10mm tapped spacers
4 M3 x 6mm pan head screws
6 M4 x 10mm pan head screws
6 M4 flat washers
6 M4 shakeproof washers
6 M4 nuts
3 6.3mm single-ended chassis-mount spade lugs (Jaycar PT-4910)
3 6.3mm double-ended 45° or 90° chassis-mount spade lugs (Jaycar PT-4905, Altronics H-2261)
Extra heavy-duty hook-up wire and spade crimp lugs for low-voltage wiring
Mains connection hardware to suit installation

Semiconductors

1 KBPC3504 400V 35A bridge rectifier (Altronics Z-0091)
2 3mm red LEDs

Capacitors

6 10,000µF 35V or 50V snap-in PC-mount electrolytics (max. 30mm diameter) (Altronics R-5601, Farnell 945-2869)
2 100nF metallised polyester (MKT)

Resistors

2 2.2kΩ 1W 5%

Transistor Quality

To ensure published performance, the MJL21193 & MJL21194 power transistors must be On Semiconductor branded parts, while the 2SA970 low-noise devices must be from Toshiba. Be particularly wary of counterfeit parts, as reported by us in the past.

We recommend that all other transistors be from reputable manufacturers, such as Philips (NXP Semiconductors), On Semiconductor and ST Microelectronics. This applies particularly to the BD139 & BD140 output drivers.

filtering at the input of the amplifier. We will describe the reasoning behind this later in the article.

Residual noise measurements have also improved. Unweighted signal-to-noise ratio with respect to 20W into 8Ω is -115dB while the A-weighted figure is -118dB.

Even though those noise figures are highly creditable, they are not low enough to enable us to accurately measure the distortion at low power (ie, below 5W). This is because the residual noise becomes a significant part of the measurement and largely masks the actual distortion. We discussed this in some detail in the July 1998 article and published some noise-averaged scope plots of the distortion products to demonstrate this mechanism. We hope to feature some equivalent scope plots next month.

For the moment, we can unequivocally state that this new class-A amplifier module is one of the lowest distortion designs ever produced, anywhere!

Circuit description

Fig.5 shows the full circuit of the

Performance: Class-A Amplifier Module

Output power: 20W into 8Ω (pure class-A); see text

Frequency response: 0dB down at 20Hz; ~0.2dB down at 20kHz; -3dB @ 1.5Hz and 190kHz (Fig.4)

Input sensitivity: 625mV RMS (for full power into 8Ω)

Input impedance: ~10kΩ

Rated harmonic distortion: <.002% from 20Hz – 20kHz, typically .0006% (Fig.2)

Signal-to-noise ratio: -115dB unweighted, -118dB A-weighted (with respect to 20W into 8Ω, 22Hz-22kHz bandwidth)

Damping factor: 180 at 1kHz

Stability: unconditional

new amplifier. While the general configuration is similar to that used in our July 1998 design, very few component values are the same. Some of the transistors have been changed, the cascode stage has been omitted, the biasing arrangements for the constant current sources (Q5, Q6 & Q7) have been significantly changed and the impedance of the input and feedback networks has been substantially reduced.

These changes were made to improve the residual noise, the power supply rejection ratio (PSRR) and the voltage efficiency of the amplifier.

In fact, the only stages which are largely unchanged are the Vbe amplifier (Q10) and the complementary-feedback pair (CFP) power output stage. So let's go through the circuit.

The input signal is coupled via a 47µF 25V electrolytic capacitor and 100Ω resistor (R2) to the base of transistor Q1, one of an input differential pair (ie, Q1 & Q2) using Toshiba 2SA970 PNP low-noise transistors. The 100Ω input resistor and 820pF capacitor (C1) constitute a low pass filter with a -6dB/octave rolloff above 190kHz.

This is a much lower impedance network than the previous design, in order to provide the lowest impedance for the signal source. In fact, a simple 20kΩ volume control, as used in the previous design, will also degrade the amplifier's noise performance and for that reason we will be presenting an active volume control circuit in a future issue.

Both the bias resistor for Q1 and the series feedback resistor to the base of Q2 are set at 10kΩ (instead of 18kΩ in the original design), again to minimise source impedance and thereby, Johnson noise.

The gain of the amplifier is set by the ratio of the 10kΩ and 510Ω feedback resistors to a value of 20.6, while the low-frequency rolloff (-3dB) of the gain is set by the 220µF capacitor to 1.4Hz. Readers may wonder why we used such large electrolytic capacitors in the input and feedback networks. The answer is that we are acting to eliminate any effects of capacitor distortion in the audio pass-band.

Readers might also wonder why we have not used non-polarised (NP) electrolytics for these functions since they are normally preferable where the capacitor operating voltage is extremely low. The answer is that NP electrolytics could have been used except for their greater bulk and we wanted to minimise any extraneous signal pickup by physically larger capacitors.

That is one of the unwanted side-effects of a much wider frequency response – the amplifier is more prone to EMI and in the extreme case, to supersonic oscillation if the wiring details are not duplicated exactly.

Diodes D1 & D2 are included across the 220µF capacitor as insurance against possible damage if the amplifier suffers a fault which pegs the output to the -22V rail. In this circumstance, the loudspeakers would be protected against damage by a loudspeaker protection module (to be published in a coming month) but the 220µF capacitor would be left to suffer the reverse current. We have used two diodes here instead of one, to ensure that there is no distortion due to the non-linear effects of a single diode junction at the maximum feedback signal level of about 1V peak.

Most of the voltage gain of the amplifier is provided by Q9 which is fed via emitter follower Q8 from the collector of Q1. The emitter follower is used to buffer the collector of Q1 to minimise non-linearity. Q9 is operated without an emitter resistor to maximise gain and output voltage swing.

The collector loads for Q1 & Q2 are provided by current mirror transistors Q3 & Q4. Similarly, the collector load for Q9 is provided by a constant current load comprising transistors Q6 & Q7. Interestingly, the base bias voltage for constant current source Q5 is also set by Q6. Q5 is the constant current "tail" for the input differential pair and it sets the collector current through these transistors.

The reason for the rather complicated bias network for Q5, Q6 and Q7 is to produce a major improvement in the power supply rejection ratio (PSRR) of the amplifier. Similarly, the PSRR is improved by the bypass filter network consisting of the 10Ω resistor and 1000µF 35V capacitor in the negative supply rail.

Why is PSRR so important? Because this amplifier runs in class-A, it pulls a constant current in excess of 1A (actually 1.12A) from the positive and negative supply rails. This is a great deal higher than the typical quiescent current of a class-B amplifier which is typically around 20-30mA.

The result of this is that the 100Hz ripple superimposed on the supply lines is about 500mV peak-peak, when two modules are connected. Hence we need a PSRR that is much higher than for a typical class-B amplifier. That is why we employed a regulated power supply for the previous class-A design.

The output signal from voltage amplifier stage Q9 is coupled to driver transistors Q11 and Q13 via 100Ω resistors. These protect Q7 and Q9 in the event of a short circuit to the amplifier output which could possibly blow these transistors before the fuses blow. The 100Ω resistors also have a secondary function in acting as "stopper" resistors to help prevent parasitic oscillation in the output stage.

As already mentioned, the output stage actually uses complementary feedback pairs, based on Q11 & Q12 and Q13 & Q14. These give a more linear performance than the more

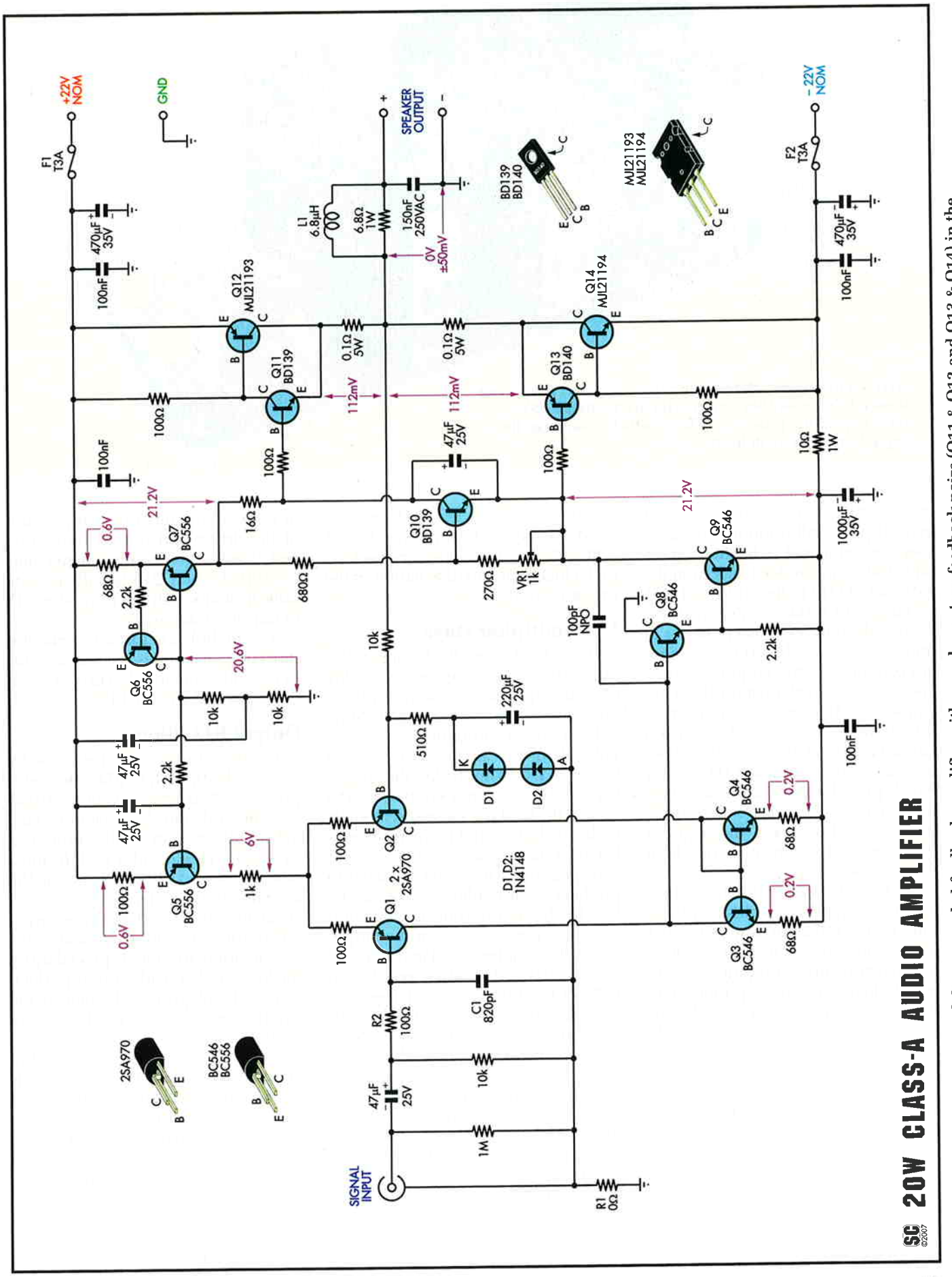


Fig.5: the circuit is a conventional direct-coupled feedback amplifier with complementary feedback pairs (Q11 & Q12 and Q13 & Q14) in the output stage. The Vbe multiplier (Q10) is adjusted to give a quiescent current of 1.12A.

Here's a preview of the power supply module. It's driven from a bridge rectifier and carries six 10,000µF 35V filter capacitors plus two LED circuits to discharge the capacitors after switch-off.

usual Darlington transistor pairs used in many push-pull amplifiers. In effect, they are connected as feedback pairs with 100% current feedback from the collector of Q12 to the emitter of Q11 by virtue of a 0.1Ω "emitter" resistor.

To make the CFP concept easier to understand, consider Q11 as a standard common emitter amplifier with a 100Ω collector load resistor. Q12's base emitter junction is connected across this 100Ω resistor and so it becomes a current amplifier stage and its collector load is the common 0.1Ω resistor which provides the current feedback to the emitter of Q11. Because there is 100% local feedback, these output pairs have unity gain and a very high degree of linearity.

We should also mention the output transistors specified for this amplifier. They are the MJL21193 and MJL21194 plastic encapsulated transistors which have been featured in quite a few of our higher-powered amplifiers over the years. They are rated at 250V, 16A (30A peak) and 200W, and are clearly far more rugged than they need to be for an amplifier of this rating.

We use them here because they are among the best complementary power transistors for linearity made by any manufacturer in the world (originally made by Motorola and now sourced by On Semiconductor).

Another circuit change in this new module is that we have used a BD139 and a BD140 as the driver transistors in the complementary feedback pairs instead of using the lower power BC337 & BC327. This was necessary because of the higher power dissipation in the driver transistors.

Vbe multiplier stage

Q10 is the Vbe multiplier and it has exactly the same arrangement as in any class-B amplifier. A "Vbe multiplier" is a temperature-compensated floating voltage source and in this case it provides about 1.6V between the bases of Q11 & Q13. Q10 multiplies the voltage between its base and emitter, by the ratio of the total resistance between its collector and emitter to the resistance between its base and emitter.

In practice, VR1 is not adjusted to produce a particular voltage across Q10 but to produce the specified quiescent current of 1.12A in the output stage. This requires a voltage of 112mV across each 0.1Ω emitter resistor. In practice too, the emitter resistors have a 5% tolerance so we average the voltage across each of these resistors at 112mV. Note: you will need a digital multimeter for this adjustment. We will have more on this next month.

An interesting point about Q10 is that we have specified a BD139 for this task instead of a much-lower rated BC547 or similar transistor which would certainly be adequate from the point of power dissipation. The reason for using the BD139 is that its package and junction does a much better job of tracking the junction temperature of the driver and output transistors and thereby gives much better bias stability. In fact, Q10 is bolted to the same heatsink as driver transistor Q11 to improve tracking.

Also included to improve temperature compensation is the 16Ω resistor in the collector circuit of Q10; a small point but still worthwhile.

Output RLC filter

The remaining circuit feature to be discussed is the output RLC filter, comprising a 6.8µH air-cored choke, a 6.8Ω resistor and 150nF capacitor. This output filter was originally produced by Neville Thiele and is still the most effective output filter for isolating the amplifier from any large capacitive reactances in the load, thereby ensuring unconditional stability. It also helps attenuate any RF signals picked up by the loudspeaker leads and stops them being fed back to the early stages of the amplifier where they could cause RF breakthrough.

Finally, as with any high-quality amplifier design, the PC board itself is a very critical part of the circuit and is major factor in the overall performance. Even small deviations in PC layout can have major deleterious effects on the distortion performance.

That's all for now. In Pt.2, we'll show you how to build the matching left and right amplifier modules and describe the power supply assembly. SC

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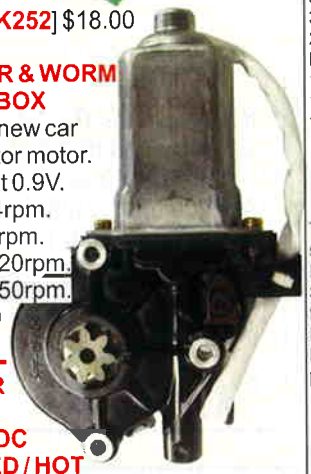

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360 DEGREE PIR KIT

This device has a 360deg. hemisphere detection zone. It has adjustable trigger on time & light settings, can be mains powered or 12VDC, we recommend 12V for safety reasons operation. 12V relay contacts O/P. Circuit diagram available via our Website. Sensor dim. dome 46dia. X 31mm(H), (91mm overall). Can be set-up to be almost impossible to approach without triggering. [**K247**] $12.50

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions from readers are welcome and will be paid for at standard rates.

LED pattern flasher uses ripple counter

This circuit uses the pulse outputs of a ripple counter to produce various patterns of LED flashing, depending on which counter outputs are selected. IC1 is a CMOS 4060B 14-stage ripple counter with internal oscillator. Two of its outputs are fed to separate diode pump circuits to drive LED1. As shown, the circuit will give a one-two-three, one-two-three flash sequence. Additional outputs can be connected by duplicating the circuits shown.

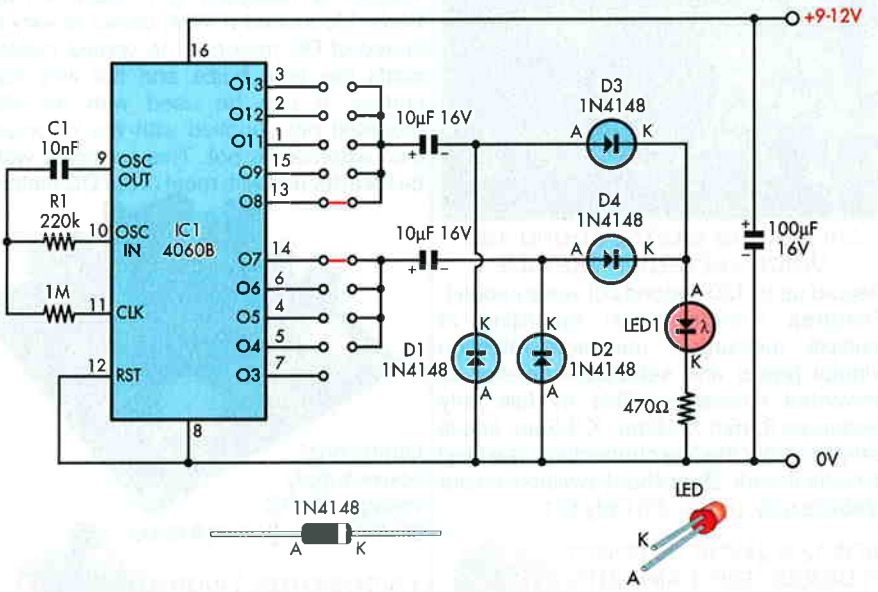
Referring to diodes D1 & D3, the diode coupling circuits work as follows. Each time the "8" output of the counter goes high, the leading edge of the pulse is coupled via a 10µF capacitor and diode D3 to LED1. When the "8" output goes low, the 10µF capacitor is discharged back into that output via diode D1, ready for the next pulse leading edge.

If you want to work out the flashing pattern of the LED, consider selected pulse outputs as a sequence of binary numbers. For example, if two adjacent outputs are used, IC1 generates the following binary sequence: 00 01 10 11 00

This produces one leading edge from 00 to 01, another from 01 to 10 and another from 10 to 11. However, there is no leading edge from 11 to 00. This creates a one-two-three flash sequence.

The flash frequency can be altered by changing the timing components and is given by the formula f = 1/(2.2 x R1 x C1), which is divided by the number of stages of IC1. LED1 should ideally be an ultra-bright LED, while the brightness of the flash can be varied by changing the capacitor value. The current drain is around 3mA.

Thomas Scarborough,
Cape Town, South Africa. ($35)



IR remote control tester has audible output

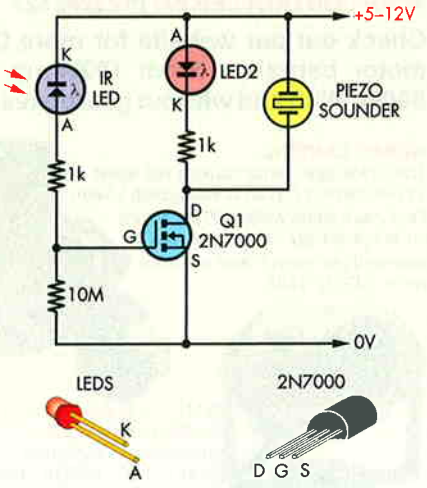
This circuit will enable you to check any IR remote control. Typical IR remote controls modulate the light at around 38-40kHz, with the data being encoded in 2.4ms, 1.2ms and 0.6ms blocks, either on or off, which repeat every 45ms until the button on the remote control is released. This circuit does not decode the infrared signal but gives a visual and audible indication that a pulsed infrared signal is present.

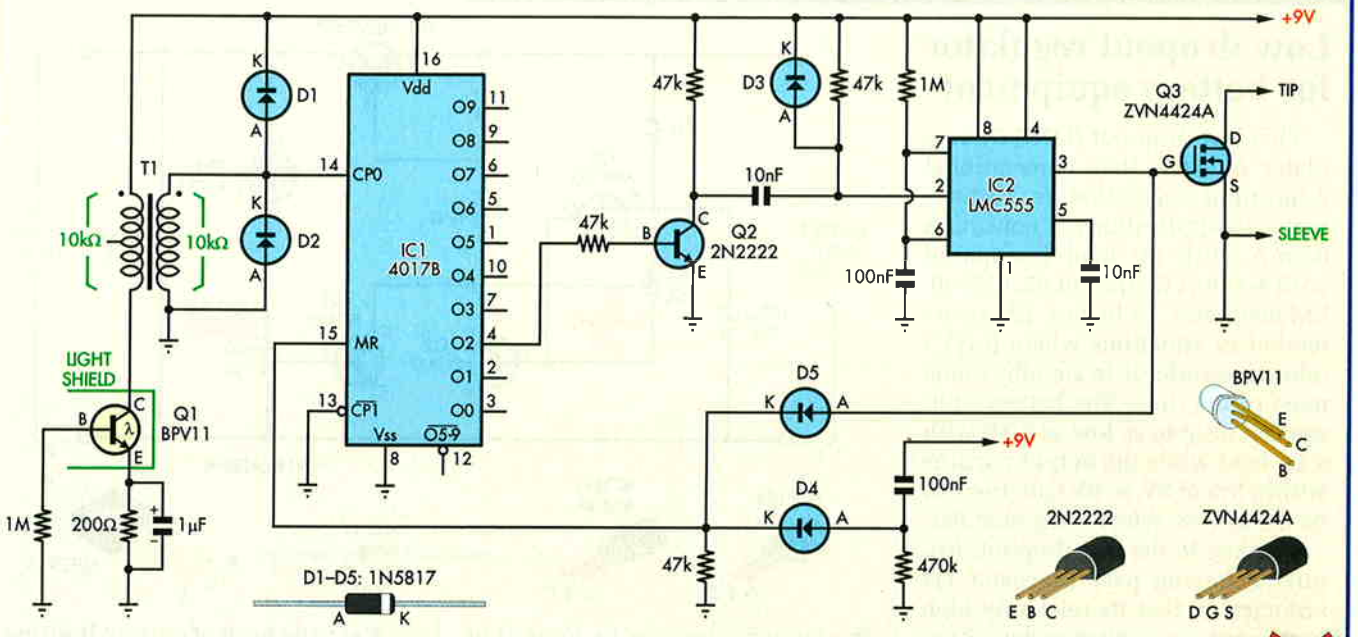
In essence, the circuit detects the bursts of 40kHz and drives a LED for visible indication and a piezoelectric transducer for the audible indication. The design makes use of the photoelectric properties of a standard IR LED; ie, it can detect as well as emit infrared light. A further benefit is that it is also partly immune to visible light.

The IR LED is reverse-biased and in the absence of light it will have a resistance of several megohms or more. When exposed to IR light, the resistance drops substantially to allow the gate of the 2N7000 FET to rise in voltage, turning it on and off to light the indicator LED and pulse the piezo transducer at the same time.

Incidentally, many web cameras and mobile phone cameras will also detect IR light from a remote control. It shows as a white light, while ever a button on the remote is pressed.

Michael Jeffery,
Eurobin, Vic. ($30)





Slave flash trigger for digital cameras

Many households have upgraded their camera equipment from film to digital but often there will be an external flashgun lying around. These flashes cannot be used with digital cameras, as the trigger voltage of around 200V would damage a digital camera's circuitry. And most, if not all, digital cameras already have a built-in flash.

However, such a flashgun can be used as a slave flash to fill up the harsh contrast that the built-in flash of typical digital cameras almost always produces. This circuit will trigger most flashguns and it uses readily available parts.

Phototransistor Q1 (a BPV11 from Dick Smith Electronics) receives the light trigger signal from the digital camera's built-in flash. Q1 drives T1, an audio interstage transformer, capable of sustaining up to 4mA without saturation. The transformer blocks any signal from ambient light and couples through the impulse signal produced by the light flash.

The transformer pulse signal is clipped by diodes D1 & D2 and coupled to the clock input of IC1, a 4017 decade counter. This device is necessary, since most digital cameras will pre-flash at least once for exposure and red-eye reduction and the slave flash would thus trigger erroneously.

IC1 is reset at power-up via diode D4 and the 100nF capacitor to the +9V supply and so its "Q0" output will be enabled. Any successive flash will advance the count and each successive "Q" output will go high. For purposes of illustration, the circuit shows output "Q2" connected, assuming that the second flash is the one where the camera actually exposes the CCD. The appropriate output should be selected to suit the camera's characteristics.

The output pulse from IC1 is inverted via transistor Q3 and AC-coupled to the trigger input of IC2, a 555 timer configured as a monostable with a 110ms period. The monostable's positive-going pulse does two things. First it biases on Mosfet Q3 which actually fires the slave flash. Second, it applies a reset pulse via diode D5 to decade counter IC1, setting it to zero to await the next flash pulses.

The circuit can be powered by a 9V battery and at rest the current consumption is quite low, dominated mostly by Q1's quiescent current produced by the ambient light.

The phototransistor should be installed inside a light shield, such as a cardboard or plastic tube 10-20mm long with a 10mm diameter and painted black on its inside.

The output transistor can be any low-current N-channel Mosfet rated for a drain voltage of at least 200V.

Fernando Garcia,
Brownsville, Texas, USA.

Fernando Garcia is this month's winner of a Peak Atlas Test Instrument

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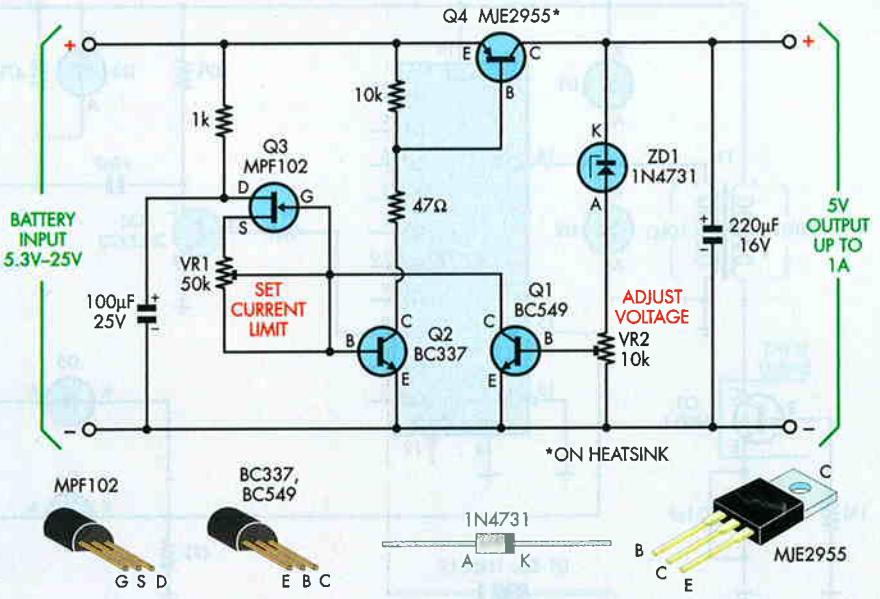
Low dropout regulator for battery equipment

This low drop-out (LDO) 5V regulator is better than conventional 3-terminal regulators in battery-powered applications. It consumes 0.2mA with no load (compared with 3-10mA for the 78L05, LM340, LM2940, etc), so battery life is extended in situations where (say) a microcontroller is in standby mode most of the time. The battery voltage can drop to as low as 5.3V with a 1A load while the output remains within 5% of 5V, so 6V batteries can be used, even when somewhat flat.

The key to the low drop-out feature is having pass transistor Q4 arranged so that its relatively high base-emitter saturation voltage is not in series with the output, only the $V_{CE(sat)}$ – a mere 0.2V or less because the MJE2955 is used well within its 10A current rating.

With no load, Q4 is barely on, with roughly 0.1mA flowing through Q4 and zener diode ZD1 and a similar amount through the rest of the circuit. We are using the zener at a current well below the several milliamp test current specified by the manufacturer, so its Vz will be less than expected, meaning that the output voltage could be less. The 10kΩ trimpot (VR1) can compensate for such variations but it helps to try a handful of 4.3-5.6V zener diodes and select one that gives the desired 5.0V output when the trimpot is near the top (zener end) of its travel. A 6.8V zener diode (eg, BZX85C6V8) is suitable for output voltages of 7.5V and above.



A simple form of current limiting is controlled by the 50kΩ trimpot. The circuit can supply up to 3A but a very good heatsink is required for Q4 and a cooling clip may need to be attached to Q2.

The maximum permissible input voltage is 25V, so 24V lead-acid batteries may exceed Q3's voltage rating.

Mark Aitchison,
Christchurch, NZ. ($40)

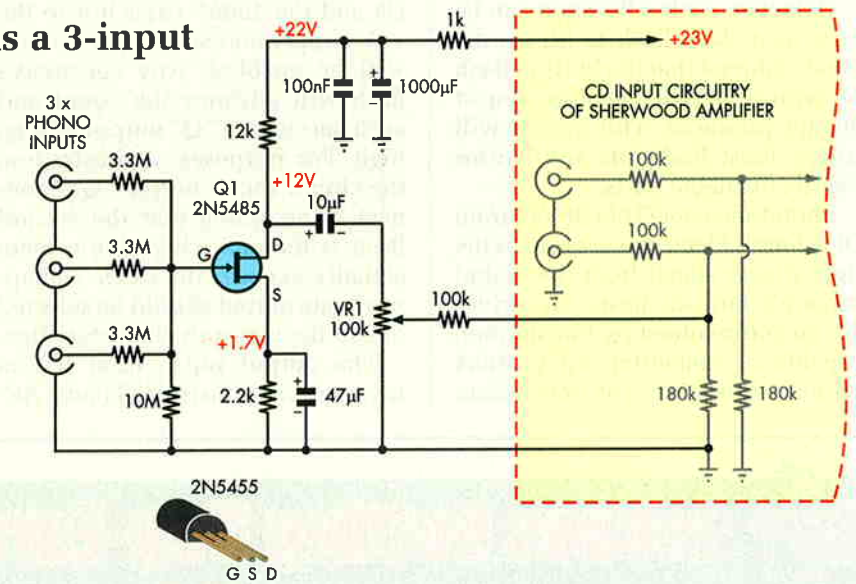
Using a stereo amplifier as a 3-input guitar amplifier

This add-on mixer circuit was incorporated into a Sherwood stereo receiver which had lost its radio function. It converts the receiver into a guitar amplifier with three high-impedance inputs and a CD input.

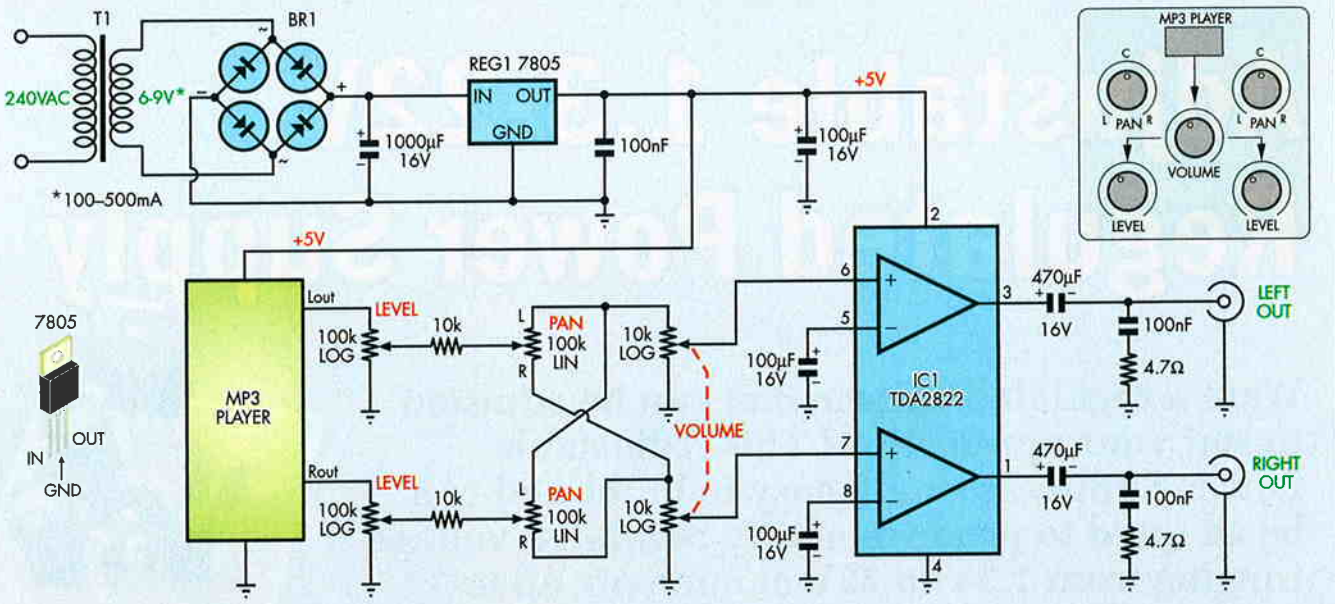
An existing internal 23V power supply was used for the mixing circuit. Three 6.5mm phone jacks needed to be added for the inputs.

The 2N5485 FET mixes the three guitar inputs via the three 3.3MΩ resistors at the gate. A volume control (VR1) follows the FET, after which the guitar signal is mixed with the CD input to the amplifier.

The original CD input circuitry was modified as shown to isolate the signals being mixed. Only one CD channel was mixed with the guitar signal. The other CD channel was similarly modified but using slightly different values in order to maintain a better balance between the two CD channels. By operating the amplifier with the mono switch engaged, all the signals eventually get fed to both speakers.



Jack Holliday,
Nathan, Qld. ($35)



Two-channel background sounds for model railways

This circuit has been designed to provide high-quality background sounds for small-scale (N or Z gauge) model railways where it is impracticable to mount speakers in the layout or where highly realistic sound is sought.

The circuit's heart is a basic MP3 player, such as a Creative MuVo, which has two entirely different soundtracks loaded into its root directory in the guise of a stereo pair. These tracks could be farm sounds and church bells, for example, or bird song and timber-mill noises. Even small capacity MP3 players can run for an hour or more. With a REPEAT function, they can run indefinitely.

The analog/headphone outputs of the MP3 player are fed via separate 100kΩ level controls to independent 100kΩ panning controls which allow each of the two signals to appear to originate from either speaker or from any position in between. The component values shown enable channel separation to be varied from 0 to -20dB.

After passing through the master 10kΩ ganged volume control, the two resulting signals are amplified by a TDA2822 dual power amplifier which can drive 4-ohm or 8-ohm loudspeakers at up to 1W/ channel but can also drive active/computer speakers. Inserting a pushbutton switch in one channel immediately before or after the level control would enable momentary activation of that channel.

If the MP3 player has a USB type-A connector built in, it can be powered via a mating connector mounted on the circuit board. Any DC voltage from 1.5V to 5V will suit many MP3 players but the TDA2822 requires 5V or more for adequate power output. DC power could be produced by the circuit shown here or obtained from a plugpack.

If powered speakers are to be used then no more than 100mA should suffice for both the MP3 player and the TDA2822. If passive speakers are used, then current requirements could total 500mA, depending on the supply voltage and speaker impedance.

A 4-channel sound system could readily be constructed by doubling the number of MP3 players, amplifiers and speakers. Joysticks could then be used to position the sounds in two dimensions rather than just the linear dimension of a stereo set-up.

Hugh Middleton,
Lower Hutt, NZ.

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Adjustable 1.3-22V Regulated Power Supply

Want a regulated voltage that can be adjusted to suit your application? This Adjustable Power Supply is small, easy to build and can be adapted to produce a fully regulated voltage ranging from 1.3V to 22V at currents up to 1A.

By JOHN CLARKE

THERE ARE MANY fixed-voltage IC regulators available and these can be had with 5V, 6V 8V, 9V, 12V & 15V outputs. But what if you want a voltage output that does not fit into one of the standard ranges or if you want to be able to easily adjust this output voltage? An adjustable regulator is the answer – one that can be set to provide the exact voltage you require.

This Adjustable Power Supply comprises a small PC board that utilises a 3-terminal regulator. It does not have too many other components – in fact, there are just three diodes, three capacitors, a resistor and a trimpot to set the output voltage from the regulator.

Circuit details

Fig.1 shows the circuit details. REG1 is an LM317T adjustable regulator that provides a nominal 1.25V between its OUT and ADJ (adjust) terminals.

We say it is a "nominal 1.25V" because, depending on the device, it can be anywhere between 1.2V and 1.3V. This doesn't really matter though, because we can adjust the output voltage to the required level using the trimpot.

Note: if you do want a regulator that provides a better tolerance for the 1.25V reference, then you could use an LD1117V instead. This has a 1.238-1.262V range. However, do not apply more than 15V to the input of this regulator.

The output voltage from REG1 is set by the 110Ω resistor (R1) between the OUT and ADJ terminals and by the resistance between the ADJ terminal and ground. This works as follows.

By using a 110Ω resistor and assuming an exact 1.25V reference, the current flow is set at 11.36mA. This is calculated by dividing the voltage between the OUT and ADJ terminals (1.25V) by the 110Ω resistor. This current also flows through trimpot VR1.

This means that if VR1 is say 1kΩ, then the voltage across this resistor will be 1kΩ x 11.36mA or 11.36V. This voltage is then added to the 1.25V reference to derive the output voltage – in this case 12.61V.

In practice, however, the current flow out of the ADJ terminal also contributes slightly to the final output voltage. This current is of the order of 100µA. So if VR1 is set to 1kΩ, this can add 0.1V to the output – ie, we get 12.71V.

If you are interested in the output voltage equation, then it is:

$$V_{OUT} = V_{REF}(1 + R1/R2) + I_{ADJ} \times R2$$

where V_{OUT} is the output voltage, V_{REF} is the voltage between the OUT and ADJ terminals, and I_{ADJ} is the current out of the ADJ terminal (typically 50µA but as high as 100µA). R1 is the resistance between the OUT and ADJ terminals, while R2 is the resistance between the ADJ terminal and ground.

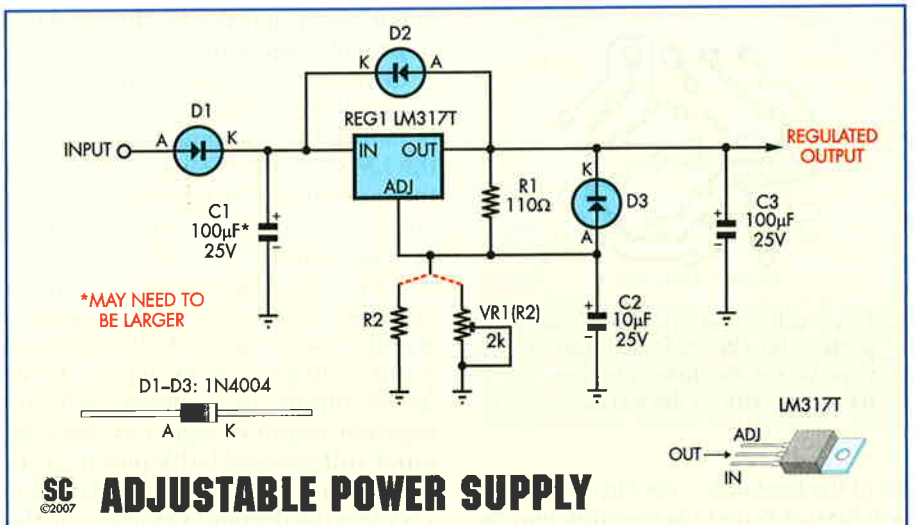
Diode D1 in series with the input provide reverse polarity protection. This means that if you connect the supply voltage around the wrong way, you cannot do any damage.

Diode D2 protects the regulator should the input become shorted to ground. If that happens, D2 becomes forward biased and conducts, effectively preventing any reverse current flow through REG1 which could cause damage.

D3 is also included to protect REG1.

Parts List

- 1 PC board, code 10105071, 35 x 38mm
- 1 LM317T adjustable 3-terminal regulator (REG1)
- 3 1N4004 1A diodes (D1-D3)
- 2 100µF 25V PC electrolytic capacitors (C1,C3)
- 1 10µF 25V PC electrolytic capacitor (C2)
- 1 110Ω 0.25W 1% resistor (R1)
- 1 2kΩ horizontal trimpot (VR1)
- 4 PC stakes



SC ©2007 ADJUSTABLE POWER SUPPLY

Fig.1: the circuit is based on an LM317T adjustable voltage regulator. D1 provides reverse polarity protection while VR1 sets the output voltage.

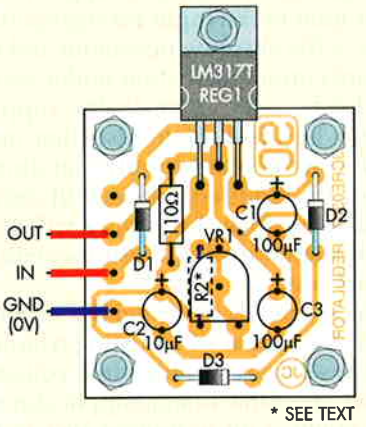


Fig.2: here's how to install the parts on the PC board.

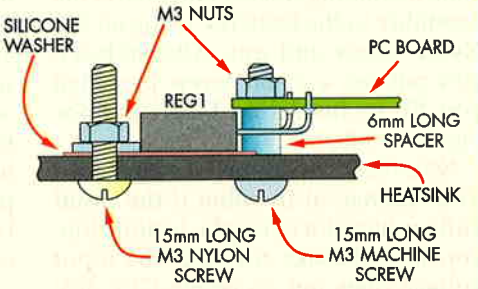


Fig.3: regulator REG1 can be mounted underneath the PC board and attached to a heatsink as shown here. Note that its metal tab must be isolated from the heatsink using a TO-220 silicone washer and a Nylon screw.

It does this by clamping the voltage between the ADJ terminal and the OUT & IN terminals in the event that one of the latter is shorted to ground.

Finally, capacitors C1 & C2 reduce ripple by bypassing the IN (input) and ADJ terminals respectively. C3 prevents regulator oscillation by swamping any low-value capacitance that may be connected to this output.

Construction

All parts for the Adjustable Power Supply are mounted on a PC board coded 10105071 and measuring 35 x 38mm. Fig.2 shows the parts layout.

As usual, begin by checking the PC board for any shorts between tracks or open circuits and make any necessary repairs. It's rare to find a board defect these days but it's easier to find any problems that might exist now, before any parts are mounted.

You can now begin the assembly by installing the 110Ω resistor (R1) and the three diodes, making sure the latter are all oriented correctly (the banded ends are the cathodes). That done, capacitors C1-C3 can be installed, again taking care with their orientation since they are all electrolytics.

Next, install PC stakes for the IN, OUT & GND terminals, then install trimpot VR1. REG1 can then be mounted. It can either be mounted on the top of the PC board (as shown in the photo) or underneath it as shown in Fig.3, so that it can be fastened to a heatsink.

Heatsinking stuff

Whether or not you need a heatsink for REG1 depends on the output current and the voltage between the IN and OUT terminals of the regulator. That's because these two values togeth-

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er determine the power dissipation within the regulator. It's determined simply by multiplying the two values together to get the power dissipation in watts – ie, P = VI.

Generally, if the dissipation is less than 0.25W, no heatsink will be required. For example, if the current drawn from the regulator is 50mA and the voltage between the IN and OUT terminals is 5V, then the dissipation will be 0.25W and no heatsink will be necessary.

However, if the dissipation is more than this , you will need to fasten the regulator to a heatsink to keep it cool. For example, let's say that the current drawn from regulator REG1 is 250mA and that the voltage across it is 5V. In this case, the dissipation will be 1.25W (ie, 5 x 0.25) and a heatsink will be necessary.

The type of heatsink required depends on the wattage dissipated by the regulator and the temperature rise that can be tolerated. Typically, a 20°C rise in heatsink temperature is OK because this means that at a typical room temperature of say 25°C, the heatsink will run at 45°C which is quite acceptable.

Most heatsinks are specified by their temperature rise in °C per watt (°C/W). This means that a 10°C/W heatsink will rise 20°C above ambient when dissipating 2W.

Note that the LM317T TO-220 package is rated at 15W maximum dissipation.

Usually, it will be necessary to electrically isolate the tab of the regulator from the heatsink – see Fig.3. The reason for this is that the heatsink may be connected to ground, while the regulator tab sits at the output voltage.

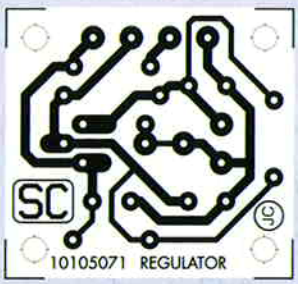


Fig.4: this is the full-size etching pattern for the PC board. Check your board for defects before mounting any of the parts.

To isolate the tab, use a TO-220 silicone insulating washer and secure the assembly to the heatsink using an M3 Nylon screw and nut. Alternatively, you can use a metal screw provided you fit an insulating bush into the regulator tab.

Note that capacitor C1 may need to be increased in value if the input voltage has a lot of ripple. In addition, you should make sure that the input voltage does not go above C1's 25V rating. Increase C1's voltage rating to 35V if it does.

In fact, you can apply up to 35V to the input if C1 is a 35V type.

Adjusting the output

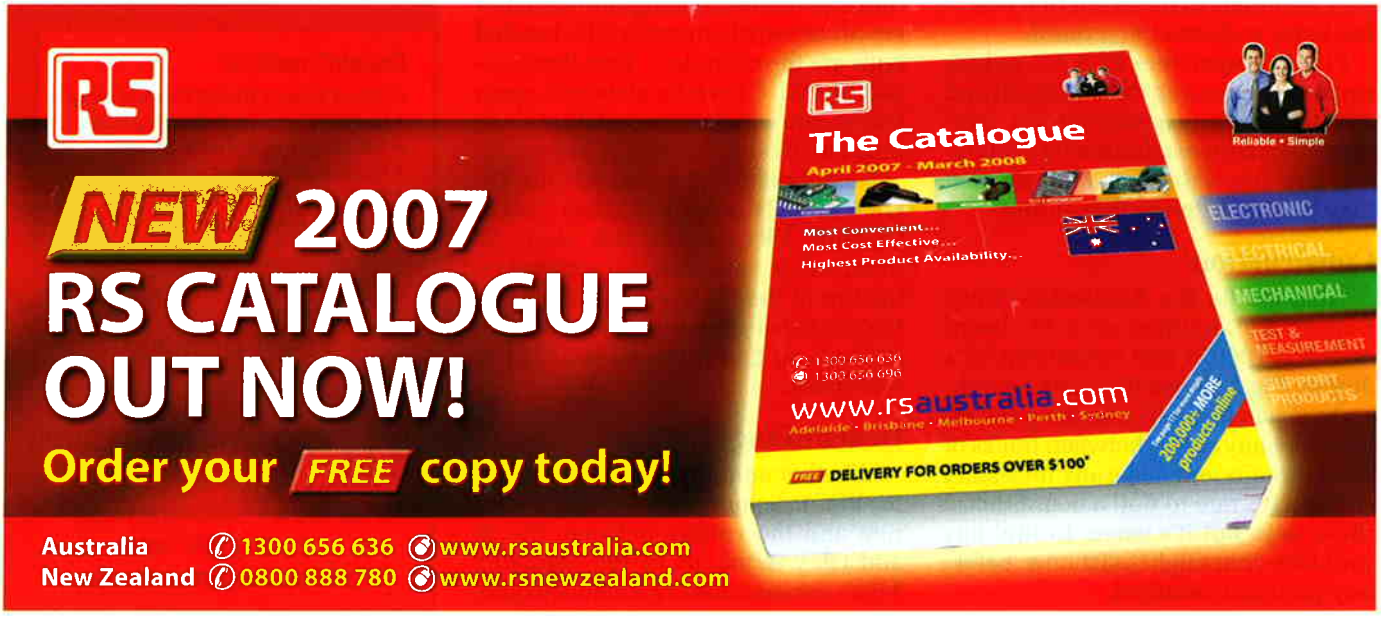
Note that the voltage applied to the supply must be several volts higher than the required output voltage. This is necessary in order for the regulator to provide regulation.

In practice, the minimum voltage across REG1 required for regulation is called the "dropout voltage". For the LM317T, this voltage varies with the current and is typically 1.5V for currents below 200mA, rising to 1.7V at 500mA and 2V at 1A.

Note that the drop across diode D1 must be added to the dropout voltage in order to calculate the required input voltage. For example, if our power supply draws 200mA and the required output voltage is 6V, then the input voltage must be 6V plus 0.7V (to compensate for voltage across D1) plus 1.5V (for the dropout voltage) – ie, the input voltage must be 2.2V higher than the output voltage.

Therefore, we need to apply 8.2V minimum to the input for regulation. This is the absolute minimum and to ensure correct regulation under varying loads, a 9V input to the supply would be ideal. Note also that any ripple on the input supply that drops below the required voltage will cause problems, since the supply will not be regulated during these low-going excursions.

Once you've connected the supply, it's just a matter of adjusting trimpot VR1 to set the required output voltage. Finally, note that in some applications, you might want to replace VR1 with a fixed resistor (eg, if VR1's setting is close to a standard fixed value). This has been catered for on the PC board – just replace VR1 with resistor R2 (shown dotted). SC



SERVICEMAN'S LOG

New fields & the whiff of cash

It's normally preferable to stick to servicing equipment that you know well in order to stay out of trouble. However, the whiff of cash can often tempt me to try my luck in fields outside my usual experience. In the long run though, it is the familiar stuff which pays the bills.

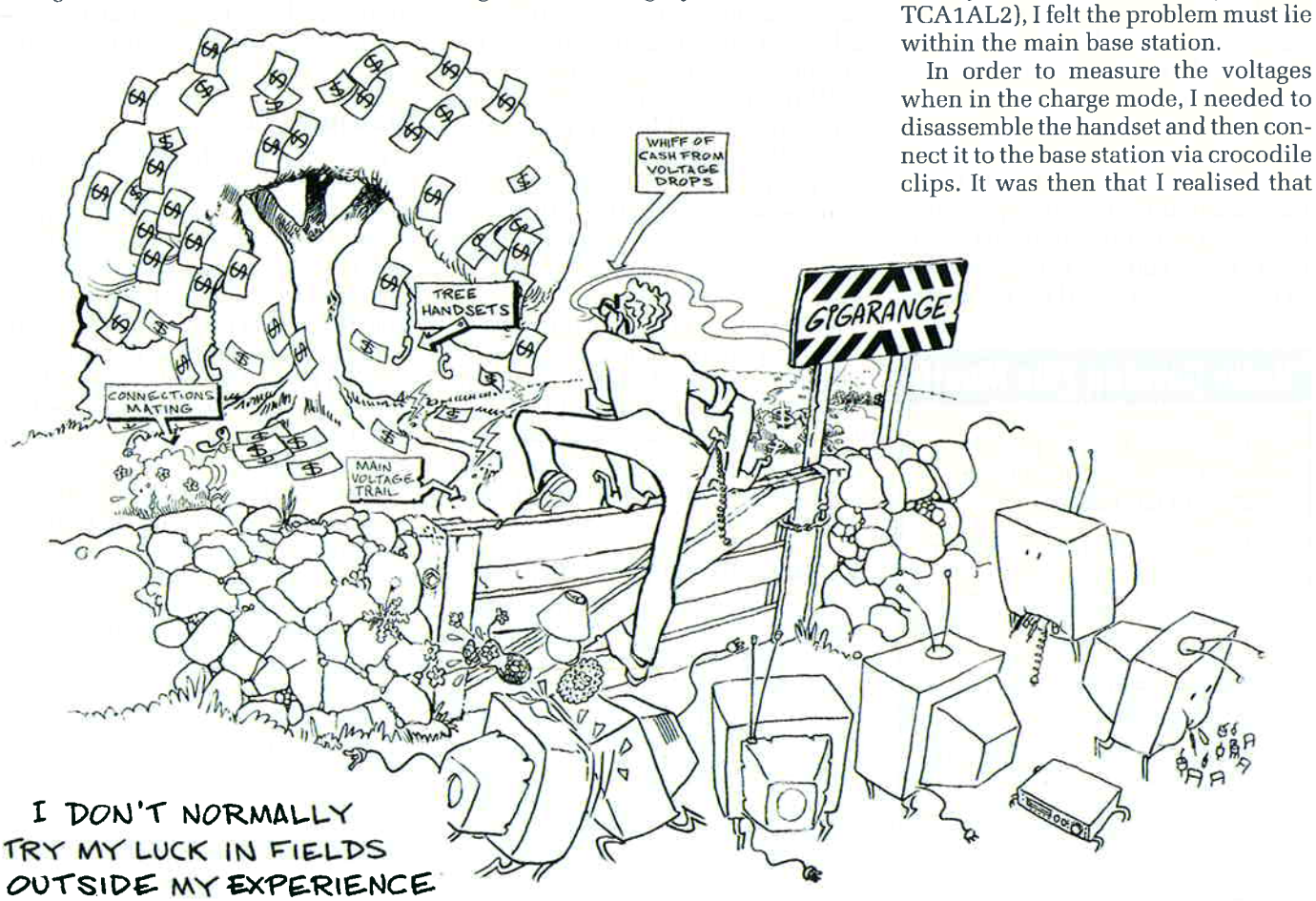
That's how it came about that I was into repairing a 2005 Panasonic 5.8GHz Digital Cordless Answering Phone System (model KX-TG5833ALM) – modestly called "GIGARANGE". Its problem seemed relatively simple and that was that it was unable to charge its battery from its main base station although it could with another charger unit.

It didn't take long to disassemble the base station to reveal a complex motherboard with microprocessors and all sorts of other surface-mounted gizmos. I quickly realised that my enthusiasm was no substitute for a service manual. Fortunately, I was able to access one of these and had to laugh when I read at the top of the front page "5.8GHz Digital Answering System with Tree (sic) Handsets". I could see I was going to get my hands dirty!

The battery used in the handsets was a 3.6V NiMH 830mAh rechargeable (HHR-P104) and the AC adaptor for the system is a 9V 500mA plugpack (PQLV1AL). The battery was absolutely flat. When the handset is placed into its cradle in the base unit, the red charge LED comes on. The voltage on the "charge" contacts without the phone is a pulsating 9V.

What I didn't realise was that the power and battery (6-hour) charge system is a sophisticated microprocessor controlled operation in both the base station and handset, where EEPROMs can also be addressed, reset and adjusted via software. Bearing in mind that I could still recharge the handset battery with another charger (KX-TCA1AL2), I felt the problem must lie within the main base station.

In order to measure the voltages when in the charge mode, I needed to disassemble the handset and then connect it to the base station via crocodile clips. It was then that I realised that


WHIFF OF CASH FROM VOLTAGE DROPS
TREE HANDSETS
GIGARANGE
CONNECTIONS MATING
MAIN VOLTAGE TRAIL
I DON'T NORMALLY TRY MY LUCK IN FIELDS OUTSIDE MY EXPERIENCE

...I TRAWLED THE INTERNET FOR A SERVICE MANUAL...

the input voltage dropped from 9V to less than 2V, which was just too low to charge the 3.6V battery.

So where was the voltage going? Obviously there wasn't a short in the handset or the base station because when disconnected it rose to 9V. And the act of the connections mating didn't induce any kind of short.

The main voltage trail from the +9V AC adaptor to the positive charge connecting button goes through D301, D362 and L361. The return path from the negative button connector is via L371, Q371 and R371, R372 & R373 in parallel, ignoring all the peripheral sensor and control circuits also hanging off these.

While under load I measured the voltage drop across each major component until I got to D362 where I found there was nearly 9V across it. Using a DVM, I almost didn't quite get the significance of this as the meter gives a 9V reading whichever way around you connect it. However, the crux of the reading was that it was +9V with the positive meter lead on the anode and the negative on the cathode; ie, there was 9V across the diode in the forward bias condition instead of only 0.6V.

Obtaining a replacement surface-mounted diode (Part No. BOECK-000008) wasn't straightforward, as the part number could not be found in the Panasonic database. However, with persistence, I eventually managed to get a substitute which fixed the problem.

Items Covered This Month

- Panasonic 5.8GHz Digital Cordless Answering Phone System KX-TG5833ALM
- Revox A77 MkIII Dolby reel to reel tape recorder
- Philips 29PT9418/79T TV set (MG3.1 chassis)
- Philips 36PW9525/79R TV set (MG3.1 chassis)
- Panasonic DMR-E55 GN DVD recorder
- Panasonic 1996 TC-25V50A MX-2A chassis

Resurrecting a revered Revox

In keeping with unfamiliar stuff, a dead 1967 Revox A77 MkIII Dolby reel-to-reel tape recorder came to me recently. This Swiss-designed and made classic deck is beautifully constructed despite its 40 years. It was one of the first fully solid-state decks with three motors, plug-in modules and solenoid controls for just about everything. It also had an electronic speed governor.

Unfortunately, this particular unit had had a hard life and was pretty rough on its exterior. I trawled the internet for a service manual where I began to learn just how highly regarded this piece of technology was as the standard in semi-professional reel-to-reel tape recorders.

The mains fuse had blown on this set due to capacitor C115 (0.47µF) having gone short circuit and taking series resistor R123 (4.7Ω) with it. Replacing these got things going but the set really needed an overhaul. All the PC boards, including the 21V B+ control P106 board, and all the module edge connectors needed cleaning. In addition, all the grey round hard plastic electrolytic capacitors needed replacing, especially C210, C211, C405, C425, C507, C509 & C813. The 24V auto-shutoff lamp had also failed and though I was tempted to replace it with a LED, I made the effort to get an original.

I am sure that enthusiasts would have many other tips available about this highly regarded deck but the work I did was enough to get this old bird back to work.

Screen burn

Last month, I touched on some unusual faults I have had with rear projection TVs. I had another interesting case recently, concerning a very popular manufacturer which has subsequently removed the product from the market entirely. This is about a 60-inch LCD 16:9 rear projection monitor (manufactured in about 2000) which had a problem due to the fact that it had been connected to a digital set top box (STB).

The set came in with two slightly green stripes running up each side of the screen where the colour changed hue. When a pure colour was displayed (eg, red, green or blue) or even sometimes white (depending on its saturation), it would show no problems. However, on grey or a detailed picture, the two bands would show quite markedly. These two bands were like a CRT screen burn but lacking slightly in contrast.

Indeed, this was in fact the LCD version of a CRT burn. The set had been run in a prolonged 4:3 format and the

two stripes were equivalent to the black border between the 4:3 and 16:9 formats.

Unlike CRTs, LCD (and plasma) elements get hottest when the picture is black because they have to cut off and absorb the light from the lamp. This light is extremely bright and very hot. In fact, the instruction book actually advises the owner not to use it in the 4:3 mode for precisely this reason.

Of course, there was nothing that could be done. The optical engine had been damaged and that was that.

Two tricky Philips sets

We had two Philips sets come in recently with one thing in common – apart from not working properly that is! One was a 36PW9525/79R and the other a 29PT9418/79T but both used the MG3.1 chassis. The latter was a 100Hz TV with twin tuners and had no colour, while the former was stuck in the Service Access Menu mode.

I chose to tackle the set with the Service Access Menu (SAM) problem first. This set had good pictures and sound as well as being almost fully functional with the remote but the SAM was permanently superimposed on top. I could navigate and change the functions within the menu but whenever I tried to exit the menu it just kept coming back. Normally, the SAM is exited via the "MENU" command or by switching off and on with the main switch but this just wasn't happening – even though it was obviously trying to.

There were no error codes in the buffer and the set did its functional test perfectly. The Option Codes were all correct too. It was as though someone was constantly trying to put it into the SAM mode. This can be done with the remote and also by shorting pins 1 & 2 of connection O356 on the Small Signal Panel (SSP). I disconnected the remote control receiver via plug O341 (pin 3) which made no difference, so I concentrated on the SSP service pins.

Pin 2 is ground and pin 1 has a 6.5V zener diode 6012 connecting it to ground. It then goes via a 470Ω resistor to pin 119 of IC7003, the OTC microprocessor. I measured the voltage on this line to find it low at 0.9V, as opposed to its cousin Service Default Mode pin 3 which was at 3.83V.

This suggested to me that this rail was being held low – but by what? The ohmmeter gave no clue as it showed both rails to have the same impedance. I unsoldered the surface-mounted zener diode but that too made no difference.

The only other clue I had was that this set was normally kept near the beach and the SSP was slightly corroded. So I removed and washed the board thoroughly before examining it carefully under a maggie-lamp. Using a continuity tester, I could find nothing to cause this problem. Besides which, if any track had gone open, surely it would remove the load on this line, not actually load it down.

Next, I tried using a link between the two service pins to see if pin 1 would rise to the same voltage as the other. It wouldn't so I concluded it was more to do with a load problem rather than a resistor strapping it to a line that had gone open circuit – if indeed there was one (I couldn't find one on the circuit diagram).

In the end, I finally assumed that there was a problem

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with the OTC microprocessor (IC7003) but I wasn't about to replace a 120-pin high-density surface-mounted IC. An exchange board, even if available, would be expensive and in any case, a corroded one is unlikely to be accepted as an exchange. And so, with the owner's consent, the set was written off.

I now moved on to the second set which had no colour. I checked it out with a signal to each of its AV inputs to find there was no colour except with the DVD component inputs which don't go near the set's colour decoder. What I did realise was that there were actually bands of colour. This told me that the colour signal was there but the burst or reference oscillator was either not working or not locking.

This set does not have a conventional colour decoder as of old but rather a digital one with phase locked loop control of the crystals. Interestingly, the PIP (picture-in-picture) had full colour but lost it when swapped with the main. The digital decoder consists of a large microprocessor (IC7501) called HIP (for High-end Input Processor) which does the luminance and chroma processing.

Using my wet finger technique, I found that when I touched the area around the 4.43MHz crystal, I could lock in the colour. When the colour wasn't locked, the picture tended to have a bit of jitter at the bottom but when locked it was perfect.

This told me that the frequency was out of range to lock to the burst signal, so I started by changing C2525, an 18pF capacitor in series with the PAL 4.43MHz reference oscillator crystal (X1525). I fitted a ceramic capacitor in place of the surface-mounted chip but this made no difference, so I directed my gaze to pin 52 of the processor which is the colour PLL.

This pin has C2522, a 3.3nF capacitor, connected to ground which is known to give a buzz in the sound. This is in parallel with resistor R3521 (100kΩ) and capacitor C2521 (100nF). Replacing all these components made no difference but I did notice a small black mark on the board near the IC. I checked the continuity of the copper track and found that is was open circuit between C2522 and pin 52. I couldn't see where the break was but fitting a wire link between the surface-mounted components fixed the problem.

Panasonic DVD recorder

The 2004 Panasonic DMR-E55 GN is a DVD recorder and analog tuner. It will only record and playback DVDs and won't record in any CD format – not even for music. It will do DVD-RAM up to 16 hours on a 9.4GB double-sided disc in EP mode and has "Time Slip" where you can record and playback at the same time.

This set doesn't give much trouble except sometimes in the power supply. If the unit stays in self-check mode or shuts down, then you can suspect IC1 (STRG6353). The easiest way to confirm this is by measuring the 12V rail with a CRO (a DVM is too slow). If it is too low or varies, then IC1 is the prime candidate.

Following some recent storms, we have been doing a roaring trade in these regulator ICs. I was given one of these models after one of the opposition decided he had gone as far as he economically could. The set had been hit in a storm and IC1 plus a few components around it had blown up and had now been replaced but the set still kept cutting off after the self-check had completed.

The voltages out of the secondary of chopper transformer T001 were all correct at +13V, +9V, +6V and +7V. However, the other rails derived from these weren't all kosher, especially the +12V rail which was low and varying, despite IC1 having been replaced.

Next, I took the board out of the set to get better access. In order to start it, I had to turn it on by shorting Q111's collector to its emitter. This in turn switches on Q110 which applies +13.5V to the DC/DC circuit.

I also switched on Q114 by shorting transistor Q107's collector to its emitter, which supplies +13.5V to a capacitor within the DC/DC circuit. That done, all the power rails came on correctly and gave me the chance to check all the voltages within the DC/DC circuit. Everything was pretty good except for the output (pin 1) of IC102 (LM2904DR) which was down from 4.3V to 2.5V despite both inputs (pins 2 & 3) being correct at 1.2V.

I thought that the surface-mounted

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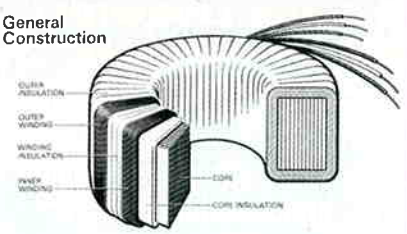
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IC might be faulty but fortunately when examining the component side minutely, I found that R115 (3.5kΩ) was cracked. It measured open circuit and a new one fixed the problem. However, what caused this surface-mounted resistor's early demise? I thought it highly unlikely it was due to storm damage as it was so far away from the damaged areas. In the end, I concluded that it was a man-made error inflicted during the earlier repair of the switching IC (IC1).

After the repair I downloaded the relevant software, made a CD and installed a firmware upgrade to update the machine from 0900EK to 0920EK.

Panasonic TV

A common fault in Panasonic TVs has been dry joints to the vertical output IC (IC451). Quite often, these dry joints are invisible to the eye but re-sweating the joints with fresh solder nearly always fixes the fault.

I had an exception the other day, though. This was with a 1996 TC-25V50A employing an MX-2A chassis. This particular set was really past its use-by date and was somewhat corroded from being near the beach.

It came in with intermittent vertical scan, another common problem. Often, a good swipe on the side of the set with your hand will bring back the vertical deflection temporarily but this set did not seem so inclined. In fact, the scan was more directly proportional to the brightness of the otherwise very dull picture. This could have meant that the tube was pretty "flat" too.

Despite this contradictory evidence, I chose to take the problem on as I was sure it was only dry joints causing the problem. I still didn't twig when I discovered that the original soldering was in fact excellent. I resoldered it anyway but to no avail.

OK, occasionally the LA7833 IC fails too, so in went a new one but there was still no joy. The vertical deflection was as intermittent as ever and no matter how much I bashed it, twisted it, froze it or heated it, it stubbornly remained that way.

But I wasn't going to be beaten by this old monster and so I decided to look at the other symptom – ie, the lack of contrast. This had to be around the ABL (Automatic Brightness Limiter) circuit which comes off the tail-end of the EHT overwind on the flyback transformer, in this case pin 3. This is decoupled to ground via capacitor C512 (0.47µF 180V).

On old Philips sets, losing capacitance in this component would give low contrast but this one measured spot-on out of circuit. I replaced it all the same and then, based on past experience, looked around for a high-value resistor nearby that might have gone open circuit. R529 (330kΩ) looked a likely candidate but it too was spot on. I then found R525 which was a weird-looking carbon resistor colour coded brown, red, violet, orange, brown. This equates to 127kΩ 1% but it measured open circuit. Bingo!

I don't stock 127kΩ resistors as they aren't in huge demand, so I made one up using 100kΩ and 27kΩ resistors in series. This fixed the contrast problem immediately and demonstrated that the picture tube was still in excellent condition. As a bonus, it also fixed the intermittent vertical scan problem as it is indirectly coupled to the vertical output IC.

Anyway, I was lucky and it put me on my guard against rash generalisations when diagnosing faults. SC

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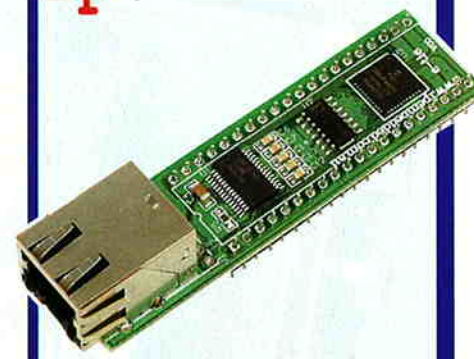

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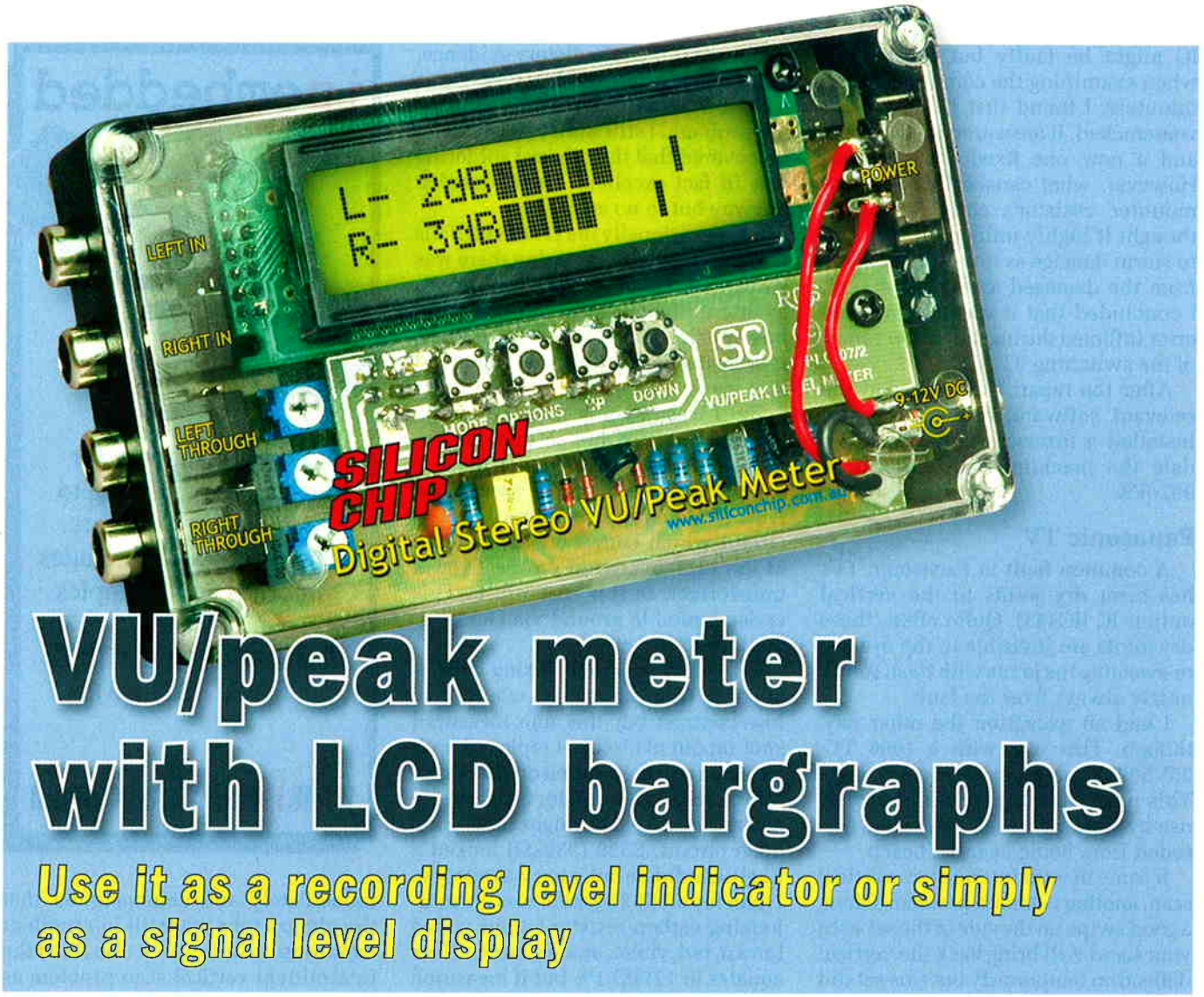

VU/peak meter with LCD bargraphs

Use it as a recording level indicator or simply as a signal level display

This easy-to-build bargraph VU meter makes it easy to record audio signals at the correct level. It shows both the average signal and peak levels in stereo on an LCD and you can adjust both the display range and number of steps. A digital display option is also available.

By JOHN CLARKE

IF YOU ARE SERIOUS about making quality recordings, then you need to accurately monitor the audio signal level being fed into the recording device. This is to ensure that the signal level is within a range that the recorder can accept.

In particular, correct audio signal levels are quite important for modern digital recorders. These do not tolerate any amount of excess signal level and will severely distort such signals.

Dynamic range

Any audio signal, be it speech or music, varies constantly in level and the difference between the highest and lowest levels is called the "dynamic range".

When recording, it's important that the lowest signal levels must be sufficiently above the "noise floor" of the recording equipment, to prevent them from being buried in noise. On the other hand, the highest signal levels must be kept low enough to prevent signal overload and the inevitable distortion that accompanies this.

Ensuring that an audio signal stays within these bounds can be quite difficult unless its level is accurately monitored using a meter. This meter must respond not just to the average signal level but to peak levels as well.

Fig.1 illustrates why it is so important to get the signal levels correct. Note that each waveform shown is not the audio signal itself but the instantaneous signal level plotted against time. These signal level variations occur constantly in music and speech. In music, for example, the level may range from soft passages to quite loud passages.

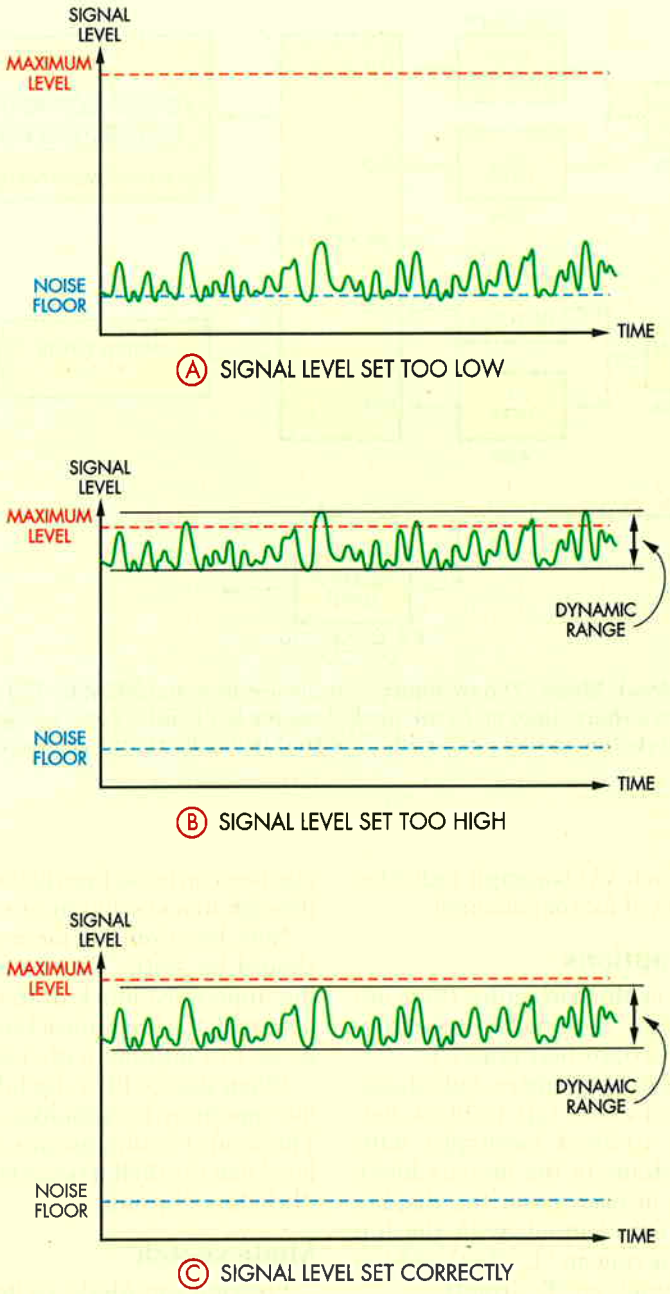

Fig.1: this diagram shows why it is important to set the correct signal level for recording. In "A", the average signal level has been set too low, resulting in lots of background noise. In "B", the level is too high and the recording system will overload and distort. Diagram "C" shows the correct level - ie, well above the noise floor but with the peaks below the maximum recording level.

Fig.1(a) shows an example of a recording that's been made with the signal level set too low. What happens here is that lowest signal levels are lost within the noise and so only noise signals will be heard at these levels. The higher signal levels are above the noise floor but the overall sound quality will be rather poor, with lots of background noise.

Conversely, Fig.1(b) shows what happens if the average signal level is too high. Here, the upper levels go above the maximum level that the recording device can handle without distortion.

For magnetic tape recording, some degree of signal peaking above the maximum level can be tolerated. That's because magnetic tape compresses the signal rather than severely clipping it. However, as previously indicated, this is not true for digital recordings where any signal that goes above the maximum is simply clipped.

The ideal recording level is shown in Fig.1(c). This is where the signal levels are well above the noise floor but do not exceed the maximum level. By doing this, we ensure both low distortion and the best possible signal-to-noise ratio.

VU meter

In the past, audio signal levels were commonly measured using a "Volume Unit" or VU meter. In fact, these have been used since broadcasting began and are still widely used by the recording industry.

In practice, a VU meter displays the average signal level and is calibrated to show the true RMS value for a sine-wave signal. The true RMS value is simply the DC equivalent value of the AC waveform.

One drawback of conventional VU meters is that they are rather slow to signal variations. Typically, they take some 300ms to respond fully to a signal and this means that they are unable to respond to the fast transients that often occur in speech and music.

As a result, many modern VU meters also include "peak displays" that show the levels of any sudden transients. However, they only show transients that are sustained for a defined time and this assumes that any short duration transients that are clipped are inaudible.

Silicon Chip VU meter

The unit described here falls into the latter category. It includes stereo (left & right channel) VU and peak level displays and employs an LCD readout (rather than a conventional meter) for a fast response.

As shown in the photos, the meter is housed in a small plastic utility case with a clear lid. It includes four RCA sockets (two input and two output) so that you can connect the unit in-line between the signal source and the recorder.

Both the Silicon Chip Stereo VU/Peak Meter and the recorder must be set up so that the meter indicates the correct levels for recording. In practice, this means that the level control on the recorder is fixed in position. Any level changes are then

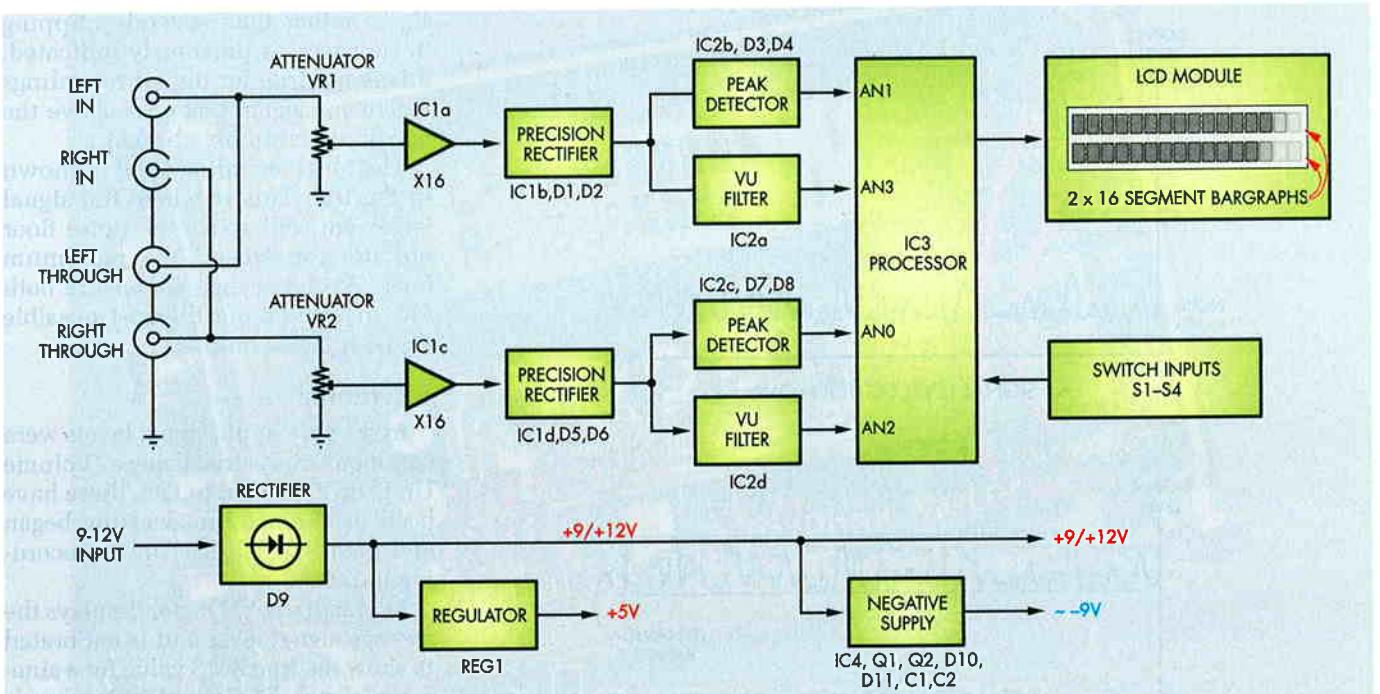

Fig.2: the block diagram of the Digital Stereo VU/Peak Meter. The incoming signals are first amplified by IC1a & IC1c and then fed to precision rectifier stages. From there, they go to the peak detector & VU filter (averaging) stages before being fed to microcontroller IC3. IC3 converts the analog peak and VU signal levels to digital values and drives the LCD module.

made at the signal source – ie, prior to the VU meter – so that both the VU meter and recorder receive the same signal level.

Alternatively, the VU/Peak Meter could be installed within the recorder itself and the signal for it derived after the recorder's level control.

The LCD readout used consists of two 16-block bargraphs (one for each channel). These bargraphs are used here for VU indication and increase in length to the right with increasing signal level.

A vertical thin line that travels ahead of each VU bargraph indicates the peak level for that channel.

Main Features

- Stereo bargraph with VU and peak displays
- 15-segment bargraph for each channel
- Adjustable thresholds for each segment
- Signal level adjustment for calibration
- Digital display option
- Programmable VU and peak display options
- 9V-12V DC power supply

Display options

As well as the bargraphs, there are several display options to choose from (ain't microcontrollers grand?).

These display options include choosing between either full 15-block bargraphs or 10-block bargraphs with digital readouts in the first six block positions. In each case, the display indicates the channel, with the top bargraph having an "L" (left) and the lower bargraph an "R" (right).

The initial pre-programmed settings are for a traditional VU meter covering the range from -28dB to +3dB as follows: –28dB, -25dB, -22dB, -19dB, -16dB, -13dB, -10dB, -7dB, -5dB, -3dB, -2dB, -1dB, 0dB, +1dB, +2dB and +3dB. These settings are the same for both channels. Note, however, that the -28dB block is not indicated because the "L" and "R" channel designations are shown here instead.

In addition, this programmed location is used when the digital format display option is selected.

The use of a microcontroller also makes it possible to change the bargraph settings to cover a wider or narrower range. In practice, each block position can be set from between -48dB through to a maximum of +16dB.

Note, however, that the overall range should be 48dB. This means that if the uppermost block in the bar is set at +16dB, the lowermost block should be set to a minimum of -32dB.

When used with a digital recorder, the uppermost bar should be set at 0dB. This would be the absolute maximum level that the digital recorder can handle before clipping.

Mode switch

Pressing the Mode switch for the first time changes the display to show the far lefthand block on the top line and the "SET VALUE" (eg, -28dB) on the second line. Basically, the block on the top line shows the bargraph position that has the indicated set value.

Pressing the Mode switch again causes the display to show the next block in the bargraph and its value. This step can then be repeated, with each subsequent pressing of the Mode switch showing the next block in the bargraph (and its value).

The displayed values can be changed using the Up and Down switches which are located behind the front panel. Note that it is important that these values are set to increase in value

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from left to right. So a sequence of -22, -19, -16, etc is correct but -22, -23, -24 is incorrect.

Options switch

The Options switch invokes the various display selections. These can be toggled using the Up and Down switches to select one of the following display options:

(1) Bar, VU On, Peak On
(2) Bar, VU Off, Peak On
(3) Bar, VU On, Peak Off
(4) Digital & Bar, VU On, Peak On
(5) Digital & Bar, VU Off, Peak On
(6) Digital & Bar, VU On, Peak Off

This means that you can select the full 15-block bargraph with both the peak and VU displays shown or you can have either peak of VU only shown. Similarly, you could choose the digital display for the first six blocks (DIGITAL selection) and then choose to show either the VU or peak readings, or both.

Note that when the DIGITAL selection is made, the digital reading will show the VU value unless the Peak display only is selected. If Peak only is selected, then the Digital display shows the peak readings.

As indicated above, the DIGITAL display uses "L" & "R" designations to indicate the left and right channel bargraphs. The digital values that are displayed will only be in steps of the actual programmed values for each block in the bargraph.

The digital display indicates these values (and the "L" & "R" designations) within the first six blocks of the displays (ie, the bargraphs no longer occupy these first six blocks). However, if the signal goes below the minimum block setting, then the digital display will show blanks instead of the numbers.

Once the display mode and other settings have been entered, the setup is saved simply by switching the power off and on again.

Block diagram

Refer now to Fig.2 for a block diagram of the Stereo VU/Peak Meter.

As shown, both the "Left In" and "Left Through" sockets are paralleled, as are the "Right In" and "Right Through" sockets. This allows the audio source signals to be fed into the VU meter and also fed straight back out to the recording device.

Following the L & R input sockets, the audio signal is fed to trimpots VR1 & VR2 which act as level attenuators. The L & R channel signals are then amplified by op amps IC1a and IC1c which operate with gains of 16. From there, the signals are then precision rectified and fed to the peak detector and VU filter stages.

The outputs from these stages are fed to the AN1-AN3 inputs of microcontroller IC3. This processes the input signal levels and drives the LCD module according to the settings and values entered using switches S1-S4.

In operation, IC3 converts the analog voltages from the peak detector and VU stages to digital values ranging from 1-1024. A value of 1024 represents the maximum analog signal level which is 5V.

Normally, the unit is set up so that the far righthand block of the bargraph turns on when signal value goes above 1024. This is set to occur when the righthand block is set at 0dB or higher. However, if the far righthand block is set at a minus dB value, then the signal value is reduced to coincide with that dB setting.

The remaining blocks in the bargraph are then calculated to show the lower signal levels. For example, a signal that is at -6dB (or half the 0dB signal level) will have a digital value of 1024/2 or 512 when converted by IC3. Similarly, a -12dB signal will have a digital value of 256. And a signal that is 48dB below the 1024 maximum level will have a digital value of 4 (ie, 251 times less).

These values are all calculated using the following equation:

Attenuation (dB) = 20log(the signal ratio)

For example, if the signal level is half the maximum, then the log of this is -0.3 and 20 times this is -6dB.

Note that IC3 only indirectly uses this equation because it uses a look-up table that already has the values programmed into it.

Power for the meter comes from an external 9-12V DC supply and this is fed in via reverse polarity protection diode D9. The resulting 9-12V rail, together with a -9V rail generated by the "negative supply" block, is used to power the op amps that form the input amplifiers, precision rectifiers, peak detectors and VU filters.

Finally, regulator REG1 produces a +5V rail which is used to power microcontroller IC3 and the LCD.

Circuit details

Fig.3 shows the circuit details but note that only the lefthand channel circuitry before IC3 has been depicted for the sake of clarity. The righthand channel is identical, so we'll describe the lefthand channel operation only.

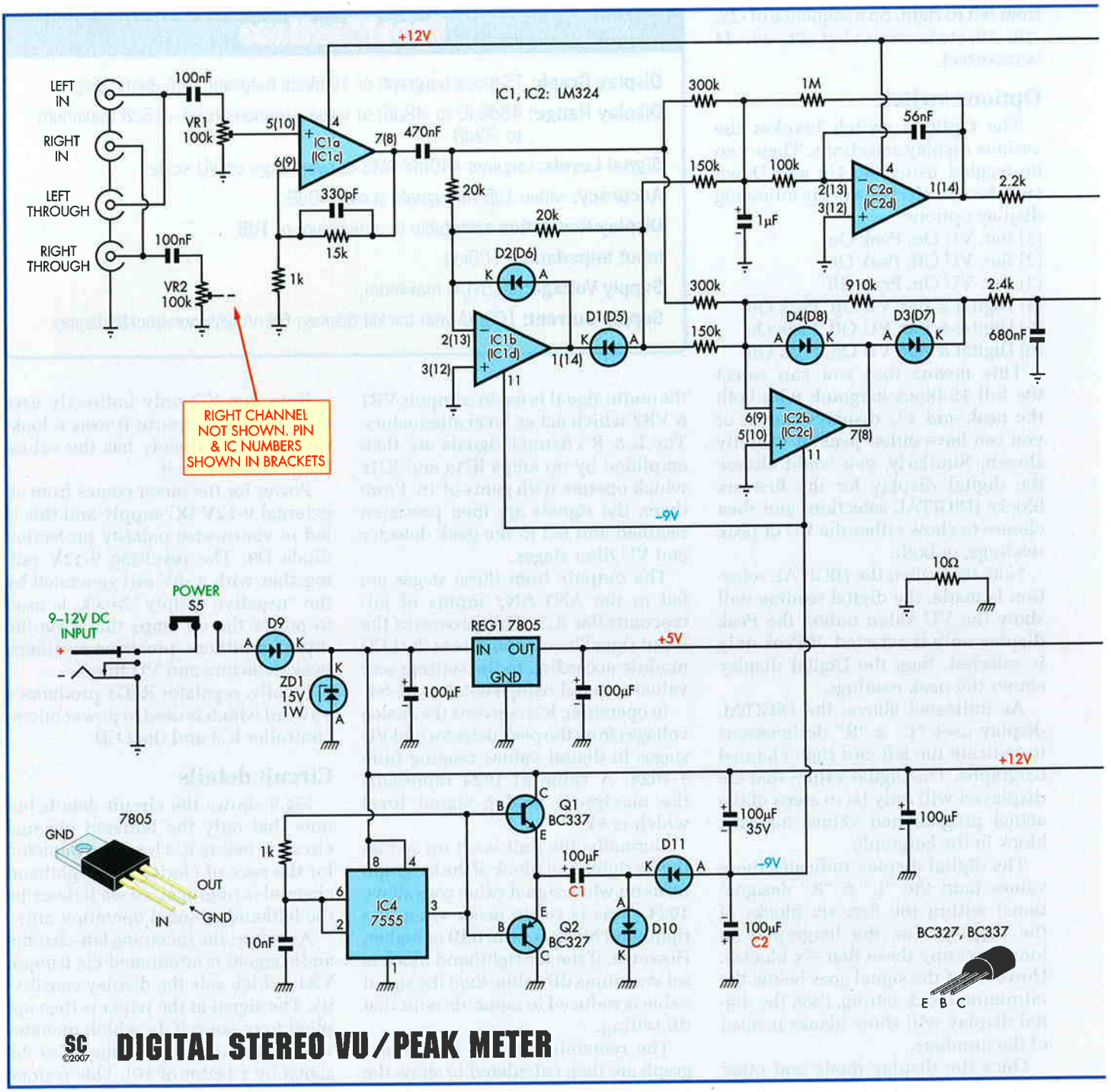
As before, the incoming left-channel audio signal is attenuated via trimpot VR1, which sets the display sensitivity. The signal at the wiper is then applied to op amp IC1a which operates with a gain of 16 (ie, it amplifies the signal by a factor of 16). This is done to boost the signal level to at least 5V peak-to-peak, so that is suitable for the following level display circuitry.

IC1a's output is fed via a 470nF capacitor to the full-wave precision rectifier. For the VU signal path, this stage is based on op amp IC1b, diodes D1 & D2 and op amp IC2a. Similarly, for the peak detector, the precision rectifier uses IC1b, D1 & D2 and op amp IC2b. It operates as follows.

When the input signal goes positive, pin 1 of IC1b goes low and forward biases diode D1. The resulting gain of the signal appearing at the anode of D1

Specifications

Display Graph: 15-block bargraph or 10-block bargraph with digital display
Display Range: 48dB (0 to -48dB) or value variations from +16dB maximum to -32dB
Signal Levels: requires 440mV RMS to over-range on VU scale
Accuracy: within 1dB for signals above -40dB
Display Resolution selectable to a minimum of 1dB
Input Impedance: 100kΩ
Supply Voltage: 9-15VDC maximum.
Supply Current: 108mA with backlit display; 68mA with non-backlit display



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DIGITAL STEREO VU/PEAK METER

is -1, as set by the 20kΩ input resistor and 20kΩ feedback resistor.

This inverted signal at D1's anode is applied to the inverting input (pin 2) of IC2a via 150kΩ and 100kΩ resistors. IC2a operates with a gain of -6.66 on this signal, as set by the ratio of the 1MΩ feedback resistor and the 150kΩ input resistor (the 100kΩ resistor in series with the input is inside the feedback loop).

As a result, the overall gain for the signal path between pin 2 of IC1b and pin 1 of IC2a is -1 x -6.66, or +6.66 (ie, IC1b's gain x IC2a's gain).

At the same time, the positive-going signal from IC1a is applied via a second path to IC2a via a 300kΩ resistor. In this case, IC2a operates with a gain of -3.33 due to the ratio of the 1MΩ feedback resistor and the 300kΩ input resistor. Thus, the overall signal gain at the output of IC2a is 6.66 - 3.33 = 3.33.

Now let's consider what happens when IC1a's output swings negative. When this occurs, diode D2 is forward biased and so IC1b's output is clamped at 0.6V above the pin 2 input signal and no signal flows through D1. IC1b is therefore effectively taken out of circuit and IC2a now simply amplifies the signal from IC1a (applied via the 300kΩ resistor) on its own.

As before, it operates with a gain of -3.33 for this signal path. Since the input signal is negative, the output at pin 1 is positive – ie, it inverts and amplifies the negative input signal.

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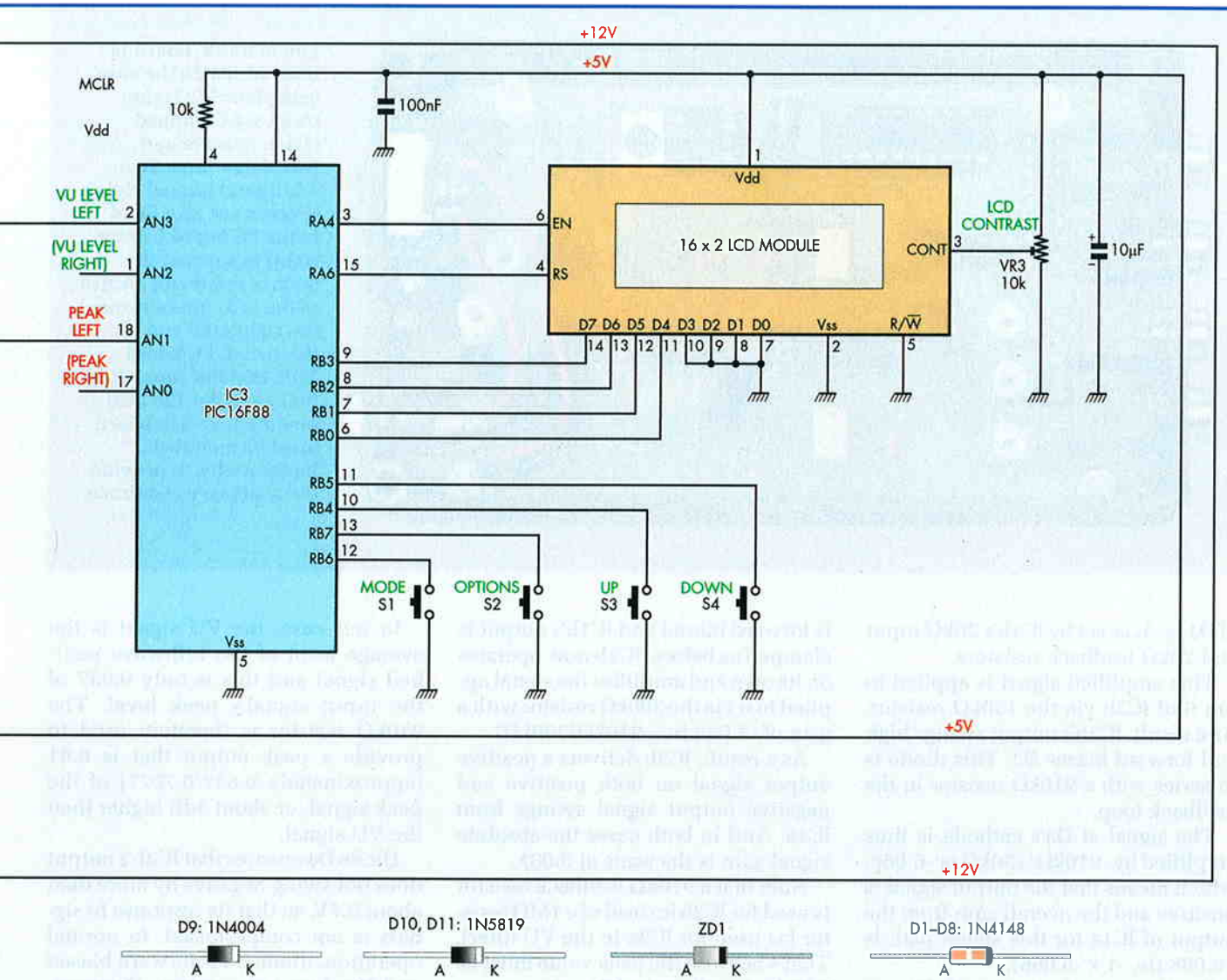


Fig.3: the parts shown in this circuit diagram can be directly related to the block diagram shown in Fig.1. Note that only the lefthand channel circuitry before IC3 has been shown for the sake of clarity – the righthand channel is identical. IC1a is the input amplifier, IC1b, D1, D2 & IC2a form the precision rectifier & VU filter stages and IC2b, D3 & D4 function as the peak detector. IC4, transistors Q1 & Q2, diodes D10 & D11 and capacitors C1 & C2 make up a diode charge pump which provides the required -9V rail.

The precision rectifier therefore provides a positive output with gain of 3.33 for both positive and negative going inputs.

VU response

IC2a also provides low-pass filtering of the rectified signal so that its response is relatively slow. This filtering conforms to VU (volume unit) standards so that the output reaches the input level after 300ms and overshoots by about 1.5%.

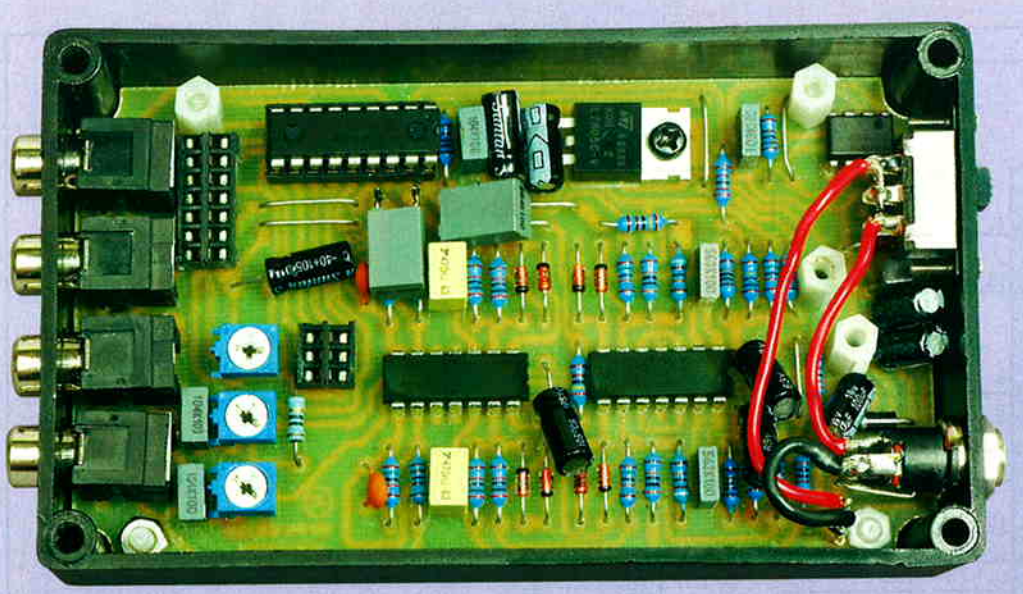
The filtering is carried out using the 100kΩ and 1MΩ resistors, the 56nF and 1µF capacitors and the parallel combination of the 300kΩ and 150kΩ input resistors. These together provide the 2.1Hz roll-off frequency and a Q (quality factor) of 0.62.

Peak level detector

IC2b and its associated components comprise the peak level detector. This stage is also fed via two signal paths: (1) directly from the output of IC1a via the 470nF capacitor and a 300kΩ resistor; and (2) from diode D1 in the precision rectifier circuitry (and a series 150kΩ resistor).

How this works is again best explained in two steps – ie, when the signal from IC1a swings positive and when the signal swings negative.

As we know from the precision rectifier explanation, when the input signal goes positive, pin 1 of IC1b swings low and forward biases D1. The resulting gain of the signal at the anode



The main PC board is secured inside the case using four M3 Nylon screws, two tapped Nylon spacers and two Nylon nuts. Two additional tapped Nylon spacers are also fitted to the PC board (centre, right) to support the bottom righthand corner of the LCD module and the righthand end of the switch PC board. Note that the capacitors that go under the LCD module & switch board must be mounted horizontally, to provide the necessary clearance.

of D1 is -1, as set by IC1b's 20kΩ input and 20kΩ feedback resistors.

This amplified signal is applied to pin 6 of IC2b via the 150kΩ resistor. As a result, IC2b's output swings high and forward biases D3. This diode is in series with a 910kΩ resistor in the feedback loop.

The signal at D3's cathode is thus amplified by -910kΩ/150kΩ or -6.066, which means that the output signal is positive and the overall gain from the output of IC1a for this signal path is +6.066 (ie, -1 x -6.066).

For the second signal path (ie, via the 300kΩ resistor), IC2b operates with a gain of -910kΩ/300kΩ or -3.033. This means that the overall gain of the signal from IC1a is 6.066 - 3.033, or +3.033.

When the signal goes negative, D2 is forward biased and IC1b's output is clamped as before. IC2b now operates on its own and amplifies the signal applied to it via the 300kΩ resistor with a gain of -3.033 (ie, -910kΩ/300kΩ).

As a result, IC2b delivers a positive output signal on both positive and negative output signal swings from IC1a. And in both cases the absolute signal gain is the same at 3.033.

Note that a 910kΩ feedback resistor is used for IC2b instead of a 1MΩ resistor (as used for IC2a in the VU filter). That's because the peak value must be 3dB higher than the VU value.

This 3dB figure comes about because the peak of a sinewave is 1.414 times the RMS value (ie, 3dB greater). Another way of saying this is that the RMS value of a sinewave is 0.7071 of the peak value.

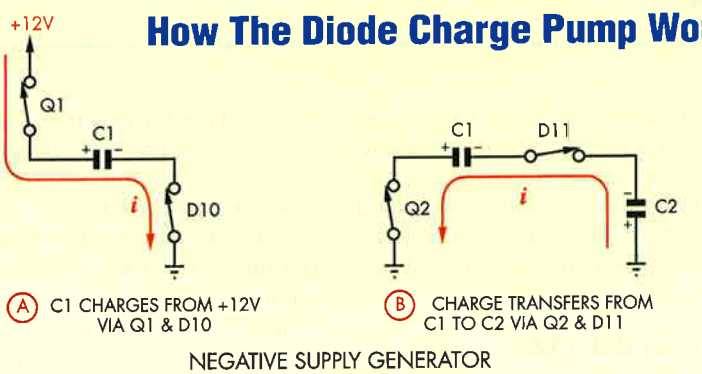


Fig.4: how the diode charge pump works. Capacitor C1 charges towards the +12V rail when transistor Q1 turns on and then transfers its charge to C2 when Q1 switches off and Q2 turns on.

In our case, the VU signal is the average level of the full-wave rectified signal and this is only 0.637 of the input signal's peak level. The 910kΩ resistor is therefore used to provide a peak output that is 0.91 (approximately 0.637/0.7071) of the peak signal, or about 3dB higher than the VU signal.

Diode D4 ensures that IC2b's output does not swing negative by more than about 0.7V, so that its response to signals is not compromised. In normal operation, diode D3 is forward biased and D4 does not conduct. However, when the signal is at 0V, IC2b's output tends to switch positive and negative to maintain control. That is when D4 comes into operation.

The peak signal level at D3's cathode is filtered using a 2.4kΩ resistor and 680nF capacitor. This filtering slows the peak signal level response so that it is not instantaneous but instead conforms to an audio standard. This ensures that only peaks that are wide enough to be audible are displayed.

The standard we picked is IEC60268-10 which has a 1.7ms response time to peak signals. This means that the measured signal level will be 1dB lower than it otherwise would be for a 10ms signal burst and 4dB lower for a 3ms burst (compared to an instantaneous measurement).

In practice, the 2.4kΩ resistor and the 680nF capacitor in the filter circuit set the time constant at 1.63ms.

The decay time constant specified

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in the IEC standard is -20dB in 1.5s (equivalent to a 650ms decay time constant). In this circuit, the 910kΩ resistor and the 680nF capacitor set the decay rate at 619ms which is near enough.

Microcontroller

The left-channel VU and peak level signals are respectively applied to analog inputs AN3 & AN1 of microcontroller IC3. Similarly, the right-channel signals are applied to inputs AN2 & AN0.

Note that the VU input signal is fed via a 2.2kΩ resistor to limit the current flow when IC2a's output goes above 5V. The 2.4kΩ resistor in the output filter circuit for IC2b does the same job.

IC3 is a PIC16F88 microcontroller. It measures the incoming VU and peak signal levels for the left and right channels and drives the 2-line 16-segment LCD module accordingly.

In operation, the signal levels at the AN inputs of the microcontroller are converted to 10-bit digital values using an internal A/D (analog-to-digital) converter. Outputs RB0-RB3 then drive the LCD's D4-D7 data lines, while outputs RA4 & RA6 drive the enable (EN) and register select (RS) lines on the LCD.

Switches S1-S4 are used to enter data into the microcontroller. Normally, inputs RB4-RB7 are held high via internal pull-up resistors. Closing a switch pulls the associated input to ground and this is detected and processed by the microcontroller.

IC3 operates at a frequency of 8MHz, as set by an internal oscillator. It is powered from a regulated +5V supply rail, with the reset input at pin 4 tied high via a 10kΩ resistor. The 100nF capacitor and a 100µF filter capacitor provide supply rail decoupling.

The LCD module also runs from the +5V supply rail and a 10µF capacitor decouples its supply. The lower four data lines (D0-D3) are tied to ground and the LCD module is driven using the upper four bits (D4-D7). VR3 provides display contrast adjustment.

Power supply

The +5V supply rail for the circuit is derived from a 9-12V DC plugpack via diode D9 (which provides reverse polarity protection) and 3-terminal regulator REG1. This regulator has its input and output terminals bypassed using 100µF capacitors. Zener diode ZD1 clamps any transients from the plugpack that go above 15V.

The positive supply rail for op amps IC1 and IC2 is derived immediately following D9 (ie, before REG1). This rail is typically 9-12V. By contrast, the negative supply rail for these op amps is generated using a diode charge pump. This comprises a 7555 oscillator (IC4), transistors Q1 & Q2 and diodes D10 & D11.

In operation, IC4 oscillates at about 75kHz, with the 10nF capacitor on pin 6 charged and discharged via a 1kΩ resistor connected to the pin 3 output. Pins 2 & 6 are the lower and upper threshold inputs and these monitor the capacitor voltage.

The pin 3 output drives the bases of transistors Q1 & Q2. When pin 3 is high, transistor Q1 switches on and Q2 is off. Conversely, when pin 3 is low, transistor Q2 switches on and Q1 turns off.

Basically, the transistors act as current buffers which drive the following voltage converter circuitry without loading IC4's the pin 3 output.

Diodes D10 & D11, along with capacitors C1 & C2 (both 100µF), act as

Parts List

1 PC board, code 01205071, 116 x 65mm
1 PC board, code 01205072, 81 x 19mm
1 LCD module with back lighting (Jaycar QP-5516 or equivalent)
1 120 x 70 x 30mm box with clear lid (Jaycar HB-6082 or equivalent)
4 SPST micro tactile switches (Jaycar SP-0600 or equivalent) (S1-S4)
1 DPDT slider switch (S5)
1 8-pin IC socket cut to 2 x 3-way strips
1 14–pin IC socket cut to 2 x 7-way strips
2 14-pin IC sockets for IC1 & IC2 (optional)
1 18-pin IC socket for IC3
4 PC mount right angle RCA sockets (Jaycar PS-0279 or equivalent)
1 20-way DIL header strip
1 2.5mm DC bulkhead socket
2 100kΩ horizontal trimpots with 2.5mm pin spacing (VR1, VR2) (Code 104)
1 10kΩ horizontal trimpot with 2.5mm pin spacing (VR3) (Code 103)
4 M3 x 10mm Nylon screws
2 M3 x 6mm Nylon screws
4 M3 x 6mm screws
1 M3 x 10mm metal screw
4 M3 tapped x 15mm Nylon stand-offs (cut to 11mm)
2 M3 Nylon nuts
1 M3 metal nut
2 M2 x 8mm screws for S5
2 PC stakes
1 100mm length of red hookup wire
1 50mm length of black hookup wire
1 200mm length of 0.7mm tinned copper wire

Semiconductors

2 LM324 quad op amps (IC1,IC2)
1 PIC16F88-I/P microcontroller (IC3) programmed with VUPEAK.hex
1 7555 timer (IC4)
1 LM340T5, 7805 5V regulator (REG1)
1 BC337 NPN transistor (Q1)
1 BC327 PNP transistor (Q2)
8 1N4148 diodes (D1-D8)
1 IN4004 diode (D9)
2 1N5819 Schottky diodes (D10,D11)
1 15V, 1W zener diode (ZD1)

Capacitors

1 100µF 35V PC electrolytic
5 100µF 16V PC electrolytic
1 10µF 16V PC electrolytic
2 1µF 16V PC electrolytic
2 680nF MKT polyester
2 470n MKT polyester
3 100n MKT polyester
2 56nF MKT polyester
1 10nF MKT polyester
2 330pF ceramic

Resistors (0.25W, 1%)

2 1MΩ	2 15kΩ
2 910kΩ	2 2.4kΩ
4 300kΩ	2 2.2kΩ
4 150kΩ	3 1kΩ
2 100kΩ	1 10Ω
4 20kΩ	

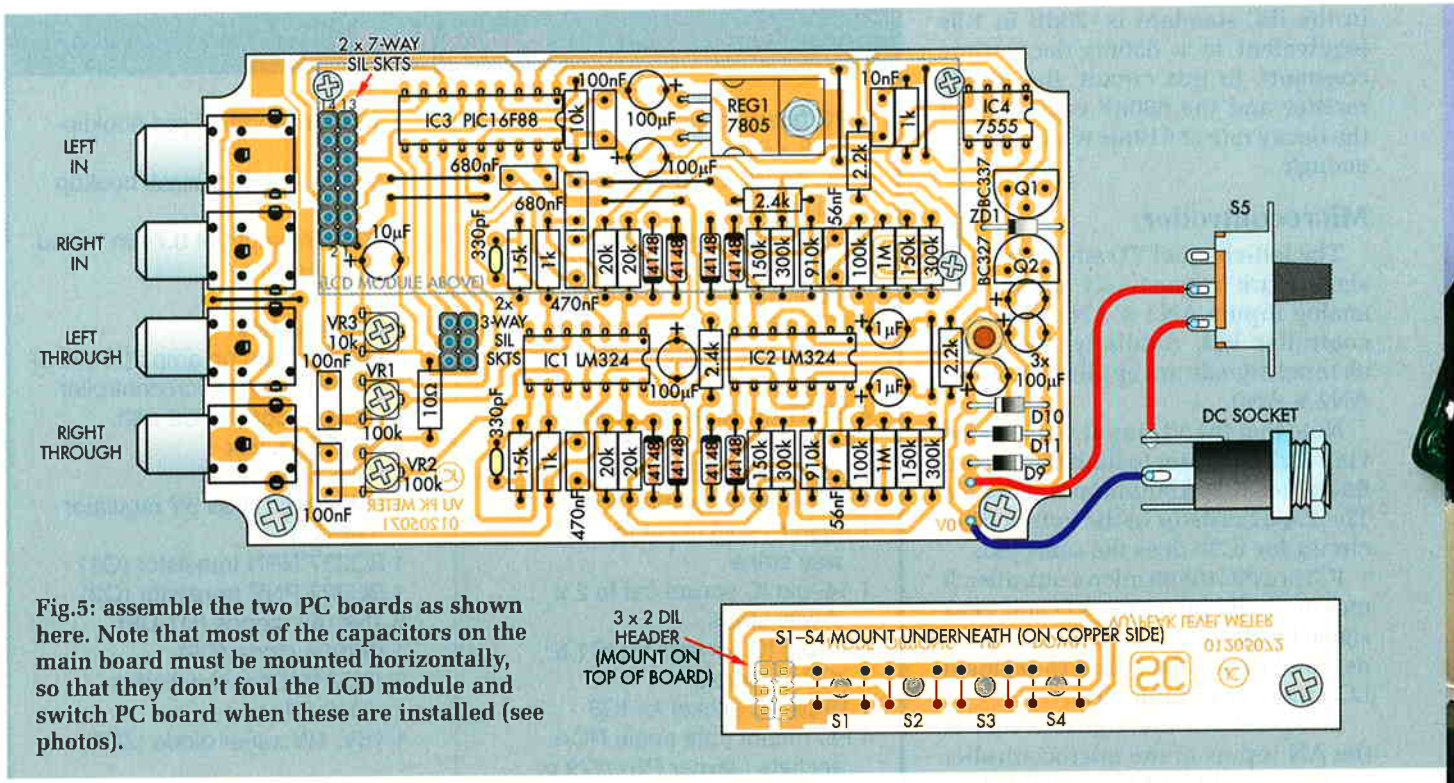
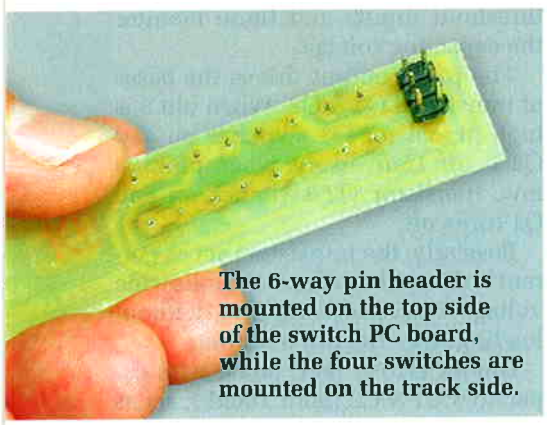


Fig.5: assemble the two PC boards as shown here. Note that most of the capacitors on the main board must be mounted horizontally, so that they don't foul the LCD module and switch PC board when these are installed (see photos).

a diode charge converter to derive the negative (-9V) supply. Fig.4 shows a more simplified arrangement of how this works.

When transistor Q1 switches on, C1 charges towards the 12V supply rail via D10. Subsequently, when Q1 switches off and Q2 turns on, the positive terminal of C1 is connected to ground and the negative side of the capacitor is pulled below ground by an amount equal to the voltage across it .

Capacitor C2 now quickly charges towards this negative voltage via diode D11. As a result, it reaches a negative voltage that is close in value to the 12V supply, minus the voltage drops across the diodes and the saturation voltages of transistors Q1 and Q2.



The 6-way pin header is mounted on the top side of the switch PC board, while the four switches are mounted on the track side.

In practice, this is about -9V and this rail is bypassed using another 100µF capacitor (to the positive rail) to minimise the supply impedance.

Note that the diodes used are Schottky types which have a lower voltage drop than standard diodes. In addition, these diodes are better suited for high-frequency operation and produce less losses at 75kHz.

Construction

The Stereo VU/Peak Level Meter is built on two PC boards – see Fig.5. The main board is coded 01205071 and carries all the input metering circuitry, the microcontroller and the LCD module which is connected via a pin header.

The second, smaller board is coded 01205072 and carries switches S1-S4 to allow the display values and options to be changed from the pre-programmed settings.

Begin by checking the PC board for any faults. These could include bridges between tracks, breaks in the copper and incorrect hole sizes. In addition, make sure that the various mounting holes are all the correct size, including those for the RCA sockets.

Start the assembly by installing PC stakes at the two supply terminals (ie, the bottom right connections to the DC socket and S5), then install the eight wire links. In particular, note the wire link situated between the two central RCA sockets – don't leave it out.

The resistors can go in next. Table 1 shows the resistor colour codes but you should also use a digital multimeter to confirm their values (some colours can be difficult to decipher).

Next on the list are the diodes. Note that several different types are used in this circuit so be careful not to mix them up. Once they're in, transistor Q1 & Q2 can be installed. Note that Q1 is a BC337 (NPN) while Q2 is a BC327 (PNP) – be sure to install them in their correct locations.

Note also that the tops of the transistors must be no more than 9mm above the PC board, to allow clearance for switch S5 when the unit is mounted inside its case.

Now for regulator REG1. As shown, this is installed flat against the board (just bend its leads down at right angles) and its metal tab secured using an M3 x 10mm metal screw and nut. Be sure to tighten the nut before soldering REG1's leads. Doing this the other way around could place undue stress on the soldered joints.

IC1, IC2 & IC4 can now be installed, taking care to ensure they are all correctly oriented (ie, pin 1 at top, right). Note that IC4 is a CMOS device, so observe the usual static precautions

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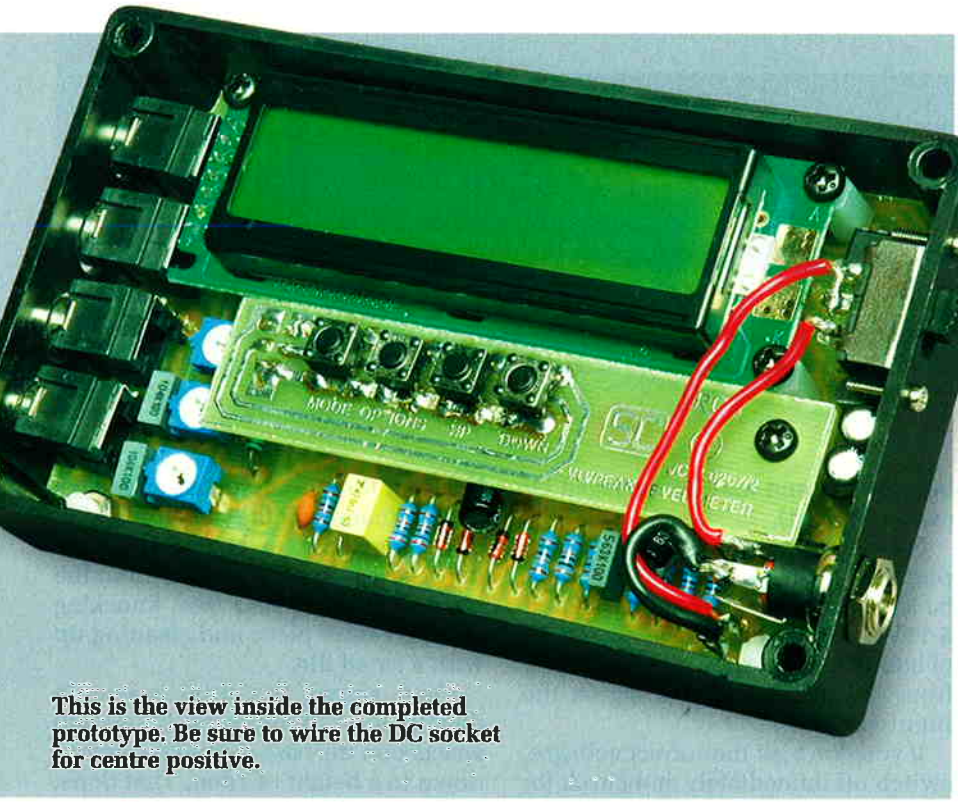

This is the view inside the completed prototype. Be sure to wire the DC socket for centre positive.

(ie, discharge yourself by touching an earthed metal object, avoid touching its pins and earth the barrel of your soldering iron using a clip lead).

An 18-pin socket is used for IC3. Don't plug IC3 in yet, though – that step comes later.

Trimpots VR1, VR2 & VR3 are next on the list. Note that VR3 is 10kΩ (code 103), while VR1 & VR2 are both 100kΩ (code 104). Once they're in, the four RCA sockets can be installed.

Installing the capacitors

Take a careful look at the photos before installing the capacitors. In particular, note that all the electrolytic types except for the two 100µF units just below Q2 must be installed horizontally (ie, laid over on their sides). This is necessary to allow clearance for the LCD module and the switch carrier PC board.

In practice, its just a matter of bending their leads down at right angles before installing them. Make sure they all go in with the correct polarity.

Depending on the brand, it may also be necessary to mount some of the MKT capacitors in this fashion.

Header sockets

The main board assembly can now be completed by installing two 7-way SIL (single-in-line) sockets (for the LCD header) and two 3-way SIL sockets (for the switch board header).

In both cases, these socket strips are made by cutting down IC sockets – ie, a 14-pin IC socket and an 8-pin IC socket, respectively. Use side cutters to split the sockets in half and a file to clean up the edges.

Once these are in, a matching 14-way pin header (which is cut from a 20-way header) can be soldered to the LCD module. Note that this header must be inserted from the underside of the module's PC board and its pins soldered on the top side.

Switch PC board

There's nothing complicated about this board, since it carries just switches S1-S4 and a 6-way pin header. Note however, that the four switches are mounted on the copper side of the board – see photo.

The 6-way header is mounted in the usual manner (ie, it is installed on the non-copper side of the board).

Testing

The unit is now ready for testing, before final assembly into its case. This should be done without microcontroller IC3 in place and with the LCD module unplugged.

First temporarily wire a DC socket

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
680nF	0.68µF	680n	684
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
56nF	.056µF	56n	563
10nF	.01µF	10n	103
330pF	NA	330p	331

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	2	910kΩ	white brown yellow brown	white brown black orange brown
❑	4	300kΩ	orange black yellow brown	orange black black orange brown
❑	4	150kΩ	brown green yellow brown	brown green black orange brown
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	4	20kΩ	red black orange brown	red black black red brown
❑	2	15kΩ	brown green orange brown	brown green black red brown
❑	2	2.4kΩ	red yellow red brown	red yellow black brown brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	1	10Ω	brown black black brown	brown black black gold brown

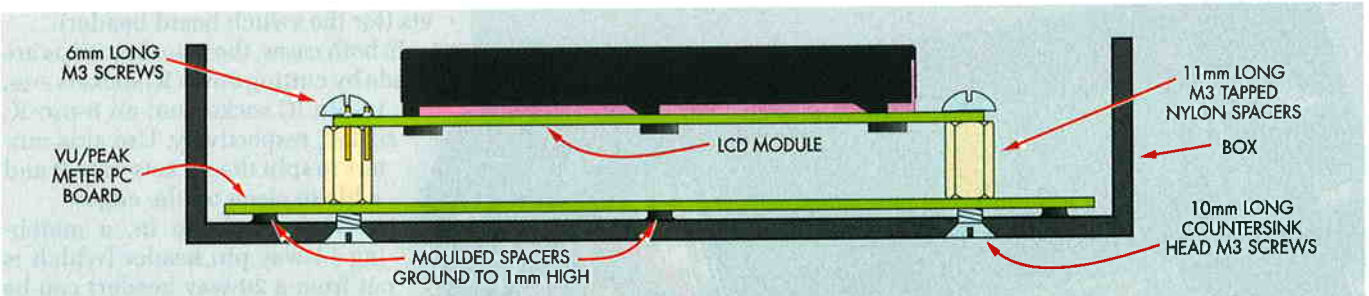

Fig.6: here's how the PC board assembly fits inside the case. Be sure to use tapped Nylon spacers as specified (not metal), to prevent shorts to the PC tracks. The 10mm countersink M3 screws through the base of the case should also be Nylon, again to prevent shorts on the PC board.

to the +12V and 0V terminals on the PC board (the +12V lead goes to the centre terminal of the socket). That done, connect a 9-12V DC power supply to the unit and switch on (warning: do not apply more than 15V to the unit, otherwise zener diode ZD1 will become hot and may be damaged by excess current).

Now measure the voltage between pins 5 & 14 of IC3's socket. This should be 5V (anywhere between 4.85V and 5.15V is OK). The voltage on pin 11 of both IC1 & IC2 should be anywhere from -7V to -10V, depending on the input voltage.

If you don't get the correct voltages, switch off immediately and check for wiring errors. If you don't get any voltage at all, check the supply polarity.

Assuming everything is OK, switch off and plug IC3 into its socket, making sure it is oriented correctly. That done, plug the LCD module into its header socket and temporarily support it at the other end on Nylon stand-offs.

Now apply power again and check that the display shows "L" and "R" to indicate the positions of the bargraphs. If there is no display or the contrast is poor, try adjusting the contrast trimpot (VR3). If there is still no display, check the connections to the module through the header and sockets.

Final assembly

Once the checkout is complete, the PC boards can be installed in a small plastic case measuring 120 x 70 x 30mm. The specified case comes with clear lid and is available from Jaycar (Cat.HB-6082).

If you are building a kit, then the case may be supplied pre-drilled. If not, then four countersunk holes will have to be drilled in the base in line with the corner mounting holes of main the PC board. In addition, you will have drill four holes at one end for the RCA sockets and a hole at the other end for the DC power socket.

Be sure to position the latter hole so that the power socket clears the switch board.

Finally, you will need to drill two holes for the switch screws and make a square cutout for the switch actuator. The square hole can be made by drilling a series of small holes around the inside perimeter and then knocking out the centre piece and cleaning up with a small file.

Fig.6 shows the final assembly details. First, the integral (moulded) spacers on the base should be ground down to a height of 1mm. That done, secure an M3 x 11mm tapped Nylon spacer (cut it down from a 15mm spacer) to the PC board immediately to the left of transistor Q2 (this spacer supports the lower righthand corner of the LCD module).

A second similar spacer is also fitted just below this (to the right of the 2.2kΩ resistor) to support the righthand end of the switch PC board.

The main board can now be installed in the case by sitting it on the 1mm moulded spacers. Secure it along the top edge using two M3 x 10mm countersink screws which go into two more M3 x 11mm tapped Nylon spacers. The bottom edge of the board is then secured using M3 x 10mm countersink Nylon screws and nuts.

Once the main board is secured, the LCD module can be installed by plugging it into its header socket and securing it to its three matching Nylon spacers using M3 x 6mm screws.

Similarly, the switch PC board is plugged into its header socket and securing it to its matching 11mm spacer at the other end.

Finally, fit the DC socket and power switch S5 and complete the wiring as shown in Fig.5. The switch is secured using the supplied M2 screws.

Calibration

Just how you calibrate the meter depends on the application. First, VR1 and VR2 are used to set the signal

DISPLAY MODES

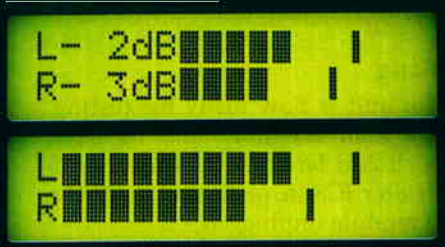

Fig.7: just two of the optional display modes that can be selected: top – Digital & Bar, VU On, Peak On; bottom – Bar, VU On, Peak On

MODE SELECTION

Fig.8: the display mode is selected by pressing the Options switch & then stepping through the selections using the Up & Down buttons. These two modes correspond to the displays shown in Fig.7.

SETTING THE BLOCK VALUES

Fig.9: the individual bargraph block values can be altered using the Mode switch & the Up & Down switches.

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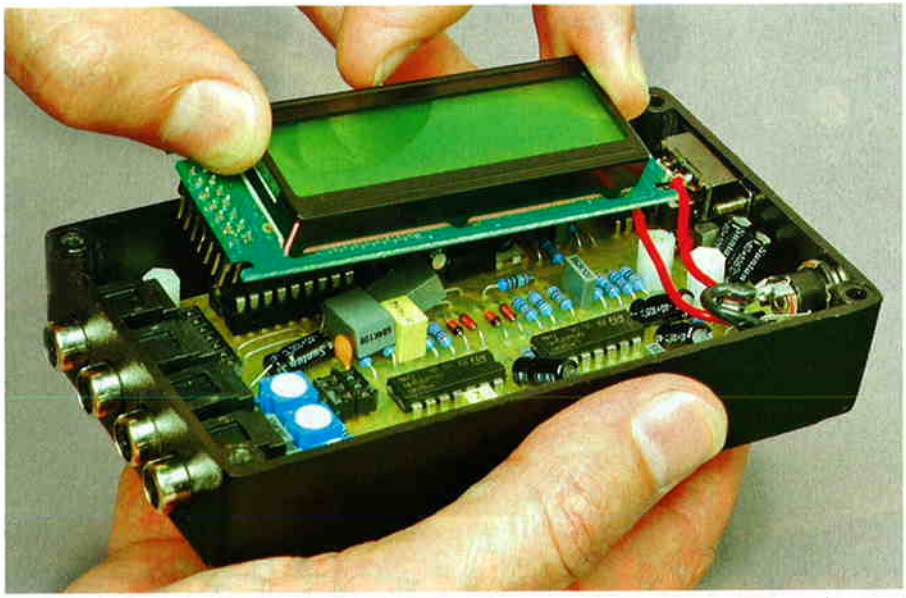

The LCD module plugs into the 2 x 7-way SIL sockets on the PC board and is secured to three of the Nylon spacers. The switch PC board (not shown here) mounts in similar fashion and is secured to the fourth Nylon spacer.

level sensitivity for the left and right channels respectively.

In practice, a true VU meter will show +0dBU when the applied signal is +4dBU. Now 0dBU is 1mW into 600Ω. Thus, when 1mW is multiplied by 600Ω and the square root taken (V = square root of Power x Resistance), the voltage is 774mV. 4dBU is 1.584 times greater and so the 4dBU signal level is 1.23V.

The peak level will be some 3dB higher than this because the peak value of a sinewave is 1.414 times higher than its RMS value. So if you are replacing existing VU meters, this Stereo VU/Peak Meter should be calibrated to show 0VU with a 1.23V sinewave input.

For most other applications, the display readings are set according to the level that produces clipping. With digital recorders, these invariably include a clipping indication that shows whenever the signal goes above the maximum level for digital conversion.

This means that the meter should be calibrated so that the 0VU peak block is just displayed at this clipping level.

The display range may also be altered to suit your application. A digital recorder would normally use a meter display that shows 0VU at the far righthand block. The values below this can then be set according to preference.

For example, you could set each block to display in just 1dB steps, or you could use much larger steps or a combination of step sizes. Larger steps are more useful at lower signal levels, while 1dB steps are best as the signal level approaches the upper threshold. SC

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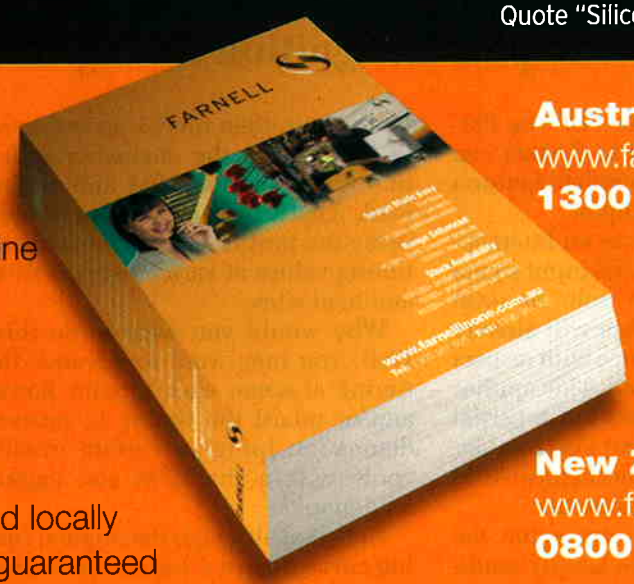

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By JOHN CLARKE

Programmable Ignition System For Cars; Pt.3

In Pt.2, we described how to build all the modules that comprise the Programmable Ignition System. This month, we describe the installation and setting up procedures and show you how to plot the ignition timing.

AS MENTIONED in Pt.1, the Programmable Ignition System can either be used as a complete ignition system or as an interceptor.

Whether it behaves as an interceptor or not depends on the input signal that's applied to the unit. In most cars, the ignition system will already provide ignition advance with respect to RPM and engine load. This applies not only to cars that have full or partial engine management but also to older cars that simply have mechanical RPM and vacuum advance systems.

When used as an interceptor, the Programmable Ignition simply modifies the existing ignition timing. By contrast, when it's used as a complete ignition system, we dispense with any existing timing system that may exist and re-map the timing using the Programmable Ignition Timing Module.

If you intend using the unit as an interceptor, then there's no real need to know what the engine's existing timing map is for RPM and engine load. That's because we are simply using the unit to modify the existing timing values at various engine RPM and load sites.

Why would you want to do this? Well, you may want to advance the timing at some sites to gain power and/or retard the timing to prevent detonation (ping) at certain trouble spots within the RPM and engine load map.

Note that although the original timing curve does not have to be known for interception, you do need to know the RPM and engine load range. This is necessary to ensure that the full mapping range is utilised with the Programmable Ignition System (more on this later).

Conversely, if the unit is used as a replacement ignition, it will be easier to program in a timing map if the original engine timing is known. That way, the Programmable Ignition can initially duplicate the original timing which can then be adjusted as necessary in a similar manner to an interceptor – eg, to extract better performance and/or to prevent detonation.

Warning!

Programming an incorrect timing map into the Ignition Timing Module could result in serious engine damage. Do NOT modify your car by fitting this device unless you know exactly what you are doing.

Also, be sure to install this ignition system in a manner that does not compromise safety. It must be ruggedly built and correctly installed to ensure that no leads or components can come adrift.

Finally, make sure that the device does not compromise the operation of other systems controlled by an existing engine management unit – eg, ABS, traction control, stability control, air-bag control, etc.

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In some cases, full timing information will be available from the car's manufacturer or from a workshop manual. Usually, however, there will be no information available.

The solution is to actually measure the timing advance against changes in RPM and engine load. This is easy to do in cars with a mechanical vacuum advance mechanism, as this operates independently of engine RPM.

Plotting the timing values in cars that use engine mapping and a MAP sensor for vacuum measurement is only slightly more difficult. It's done by externally altering the pressure sent to the MAP sensor or actuator. The exact procedure is described in the panel headed "Plotting The Original Ignition Timing Values".

Cars that utilise Mass Air Flow (MAF) sensing of engine load are much more difficult when it comes to mapping ignition advance. That's because the engine will have to be run with varying degrees of load throughout the RPM range and this can only be achieved on a dynamometer.

Interceptor or replacement?

Note that the Programmable Ignition System should be used only as an interceptor on cars that already have an engine management system. That's because the manufacturer's timing map will have been carefully designed for your engine. Furthermore, the timing would have been mapped against air inlet temperature, engine temperature and the air-fuel ratio to provide the best performance in all conditions.

By using the Programmable Ignition System only as an interceptor in such cars, the original timing variations according to fuel ratio, temperature, RPM and load will be retained.

By contrast, we do advocate using the Programmable Ignition System as a complete replacement in older cars and Go-carts and on engines that do not currently include RPM or vacuum advance.

Many old cars provide both RPM and vacuum advance by mechanical means. Because of their age, the RPM advance system is now likely to be worn and sticky in its operation, while the vacuum actuator will often be leaky or may have failed altogether. Most drivers do not notice if a vacuum actuator has failed because when it fails, it remains at the maximum engine load position. As a result, power under load is retained.

Timing Problems With Reluctor Triggers

In some cars, when using the Programmable Ignition, you may find that the ignition trigger exhibits a type of stiction effect, with the timing initially failing to advance from about 0-5°. This effect is due to the coil firing just before the trigger signal (due to the advance setting) and the resulting high-tension signal within the distributor then interfering with the normal operation of the trigger sensor.

Reluctor triggers are the most likely to be affected in this way. Hall Effect, optical, engine management and points triggers are unlikely to be affected.

In some cases the effect may be dialled out by careful adjustment of VR1. Also, make sure the high-tension lead and the reluctor leads are spaced well apart and only intersect at right angles if they do need to cross.

If this does not solve the problem then you can avoid programming low values of advance into the Programmable Ignition. This can be done in one of two ways. First, the static timing can be set to say 10° of retard (eg, –10°) so that you need at least 10° of advance from the Programmable Ignition to get 0° timing. Of course, the entire timing map would have to be changed to include this extra 10° for all values.

An alternative method is to set the static timing to greater than the maximum amount of advance in the timing map. This value would then be subtracted from required timing value for each map site in order to determine the retard setting required for each site in the Programmable Ignition.

For example, if the static timing is +40° and the timing map value is 22°, the programmable ignition map setting would be -18° (22° - 40° = -18°).

Our experience

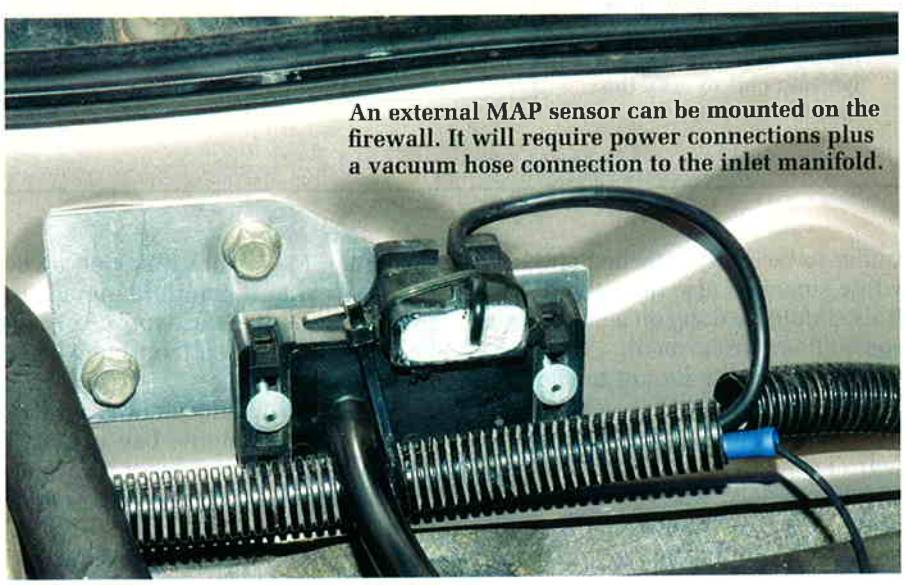
During our tests, we eliminated the original mechanical RPM and vacuum advance systems in a 1988 Ford Telstar and used the Programmable Ignition System to provide the timing advance instead. As a result, the engine became far more responsive to throttle changes and was more willing to rev than before.

There are a couple of reasons for this improved performance. First, the flying weight system in the distributor that provides RPM advance is fairly sluggish to respond to RPM changes. By contrast, the Programmable Ignition System provides "instantaneous" changes to the timing map.

Similarly, the vacuum actuator that moves the distributor's trigger firing point is slow to respond compared to using a pressure (or MAP) sensor with the Programmable Ignition System.

Installation

Typically, the Ignition Timing Module is best mounted inside the cabin of the car; eg, somewhere under the dashboard. This allows the Hand Con-



An external MAP sensor can be mounted on the firewall. It will require power connections plus a vacuum hose connection to the inlet manifold.

Plotting The Original Ignition Timing Values

IT'S QUITE EASY to plot the timing advance values for an existing ignition system by using a timing light. In fact, there are several ways to go about this.

Typically, most cars only provide timing marks that show Top Dead Centre (TDC) and up to about 10° or 12° before TDC using a scale on the engine block. These marks are ideal for setting up the ignition timing at idle but are not sufficient to measure advance at higher RPM values. This is because the advance will go beyond the 10° or 12° timing mark.

One way round this is to make up an extended timing scale to directly indicate the advance at higher RPM values. Another option is to use a timing light that includes advance adjustment.

Yet another option is to use the Programmable Ignition System and a spare ignition coil and spark plug. This system can shift the timing light's stroboscopic flashing so that it is delayed by as many degrees as the advance. That way, you can use the existing engine timing marks.

Fig.23 shows how to set this system up. Note that **the coil shown here is not the ignition coil used in the car** but a separate one that independently fires the timing light. If you do not have a spare coil, they are readily available from automotive wreckers or you could temporarily borrow one from another car (just about any single output ignition coil can be used).

The spark plug is necessary to provide a spark gap for the coil to discharge. This is important because if the coil's high tension output is left open, there is the risk that the coil will internally breakdown and suffer permanent damage.

The Ignition Timing Module takes its signal from the car's trigger sensor or existing ECU output but note that this signal must include the timing advance (not always the case with trigger sensor information). If the trigger signal does not include the timing advance, then be sure to use the output from the ECU.

Before actually plotting out the timing values, there are a number of adjustments that must first be made to the Ignition Timing Module, as follows:

Reluctor adjustment

If your car uses a reluctor pick-up, then VR1 (on the Ignition Timing Module) must first be adjusted. Begin by setting VR1 fully clockwise and measure the voltage at pin 6 of IC1. If the voltage is close to 0V, wind VR1 anticlockwise several turns until the voltage at pin 6 of IC1 goes to +5V. When it does, wind VR1 anticlockwise about two turns more and leave it at this setting.

If the voltage at pin 6 of IC1 is +5V when VR1 is wound fully clockwise, then rotate VR1 fully anticlockwise and wind it clockwise until the voltage goes to +5V. As before, wind VR1 on by an extra two turns (clockwise this time).

Initial settings

Now for the programmed settings.

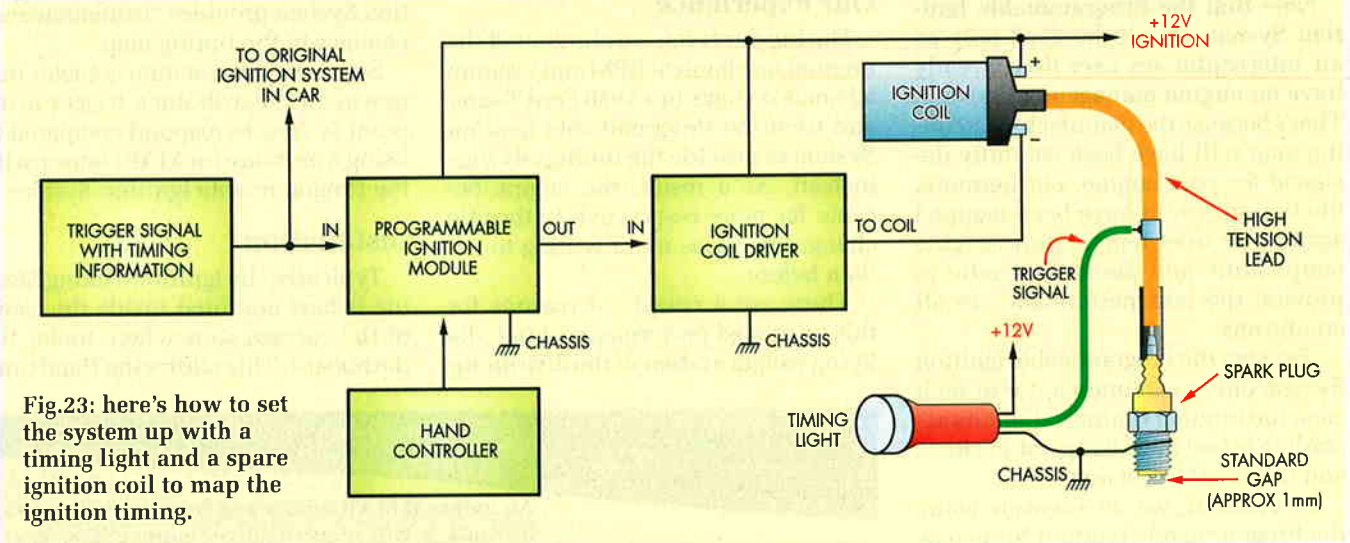


Fig.23: here's how to set the system up with a timing light and a spare ignition coil to map the ignition timing.

troller to be easily attached and used while someone else does the driving (this should be done on a racetrack or some other closed road).

It is also best to mount the Ignition Timing Module in the cabin if the Sensym pressure sensor is used. This helps keep the sensor cool.

Alternatively, the Ignition Timing Module can be mounted in the engine bay if you cannot find room for it in the cabin. Make sure it is well away from the exhaust manifold though, to prevent excessive heat exposure. It can be mounted using suitable brackets to the chassis.

The big disadvantage of mounting the unit in the engine bay is that it is much harder to connect the Hand Controller for driving. In some cases, it may be possible to feed the connecting lead through a window and under the rear of the (closed) bonnet. Alternatively, it may be possible to temporarily feed the connecting lead through the firewall (not so easy) or through an air vent (easier).

Note that the lid of the Ignition Timing Module must be left off when the Hand Controller is connected. This also allows jumper LK1 to be easily changed, to select either the settings or timing display modes. **Note that**

Here's the step-by-step procedure:
(1) Install jumper LK1 in the settings position.
(2) Set the number of cylinders for your car, the edge sense to HIGH and the diagnostic setting to "No Interpolation".
(3) Set the dwell to 0ms and set the oscillator to ON.
(4) Increase the dwell value until the timing light fires reliably. Note that the dwell value does not change until the Up switch on the Hand Controller is released.
(5) Move LK1 to the timing position and press the Reset switch on the Hand Controller so that all the timing values for the selected map return to 0.

If you now start the engine and aim the timing light at the flywheel timing marks you should see the amount of advance. If this does not seem correct, then change the edge sense to low in the settings mode (ie, temporarily move LK1 back to the settings position). If the strobing is erratic, try selecting the 2ms debounce option (again found in the settings mode).

Note that with this strobe set-up, the timing light will fire for every spark firing rather than just for cylinder 1. This will make the visible contrast of the timing mark a little less than it otherwise would be. You can compensate for this by dabbing some white paint on the flywheel marker.

Checking the advance

Having gone through all these initial adjustments, the next step is to disable any vacuum advance by removing and plugging the rubber hose that connects to the vacuum advance pressure sensor (or MAP sensor. The timing advance at idle should be set according to the manufacturer's specifications.

For the Ford Telstar, the initial timing is 6° BTC (before top centre) and this should be indicated by aiming the timing light at the timing marks. In this case, the Ignition Timing Module can now be programmed (using the Hand Controller) for a timing advance of -6.0° (retard). When this is done, the timing light should now show the timing to be at exactly TDC on the flywheel marks.

		RPM0	Min RPM									Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1												
	LOAD2												
	LOAD3												
	LOAD4												
	LOAD5												
	LOAD6												
	LOAD7												
	LOAD8												
	LOAD9												
	LOAD10												
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 1: this table shows the interpolated advance values vs RPM for the high load site (in this case, LOAD11). These values are measured with the vacuum advance line disconnected and plugged – see text.

Plotting the RPM advance values from here is straightforward. It's just a matter of running the engine at specific RPM values and adjusting the "retard" value programmed into the Ignition Timing Module until the timing light shows TDC in each case. The programmed values then represent the timing advance (in degrees) for each selected RPM value.

For example, let's say that the programmed value necessary for the timing light to show TDC is -22° when the engine is doing 3400 RPM. This simply means that, in this particular case, the standard ignition has a timing advance of 22° at that engine speed.

OK, so how do we actually do this? Simple – just select the timing display mode (using LK1) and then select DIAG so that the RPM is displayed. You can now plot out the advance versus RPM values by increasing the engine RPM in suitable steps (eg, 1000 RPM) all the way to the red line and adjusting the programmed retard value so that the timing is shown at TDC. Keep a record of these advance values as you proceed.

This RPM versus timing advance is generally the high-load map because the vacuum advance line is disconnected and plugged. However, it is not the high load map for turbo-boosted engines (see below).

The recorded timing information can now be plotted out on a graph and the interpolated values transferred to the individual RPM sites. This is done as follows:
(1) Decide whether you want the two 11x11 maps or the single 15x15 map and select this in the settings mode.
(2) Select either 1° or 0.5° resolution.
(3) Set the Minimum RPM and Maximum RPM values to suit the range of the engine. The Minimum RPM value is simply the idle speed, while the Maximum RPM value is the engine red line. The idle speed can be measured by setting the display to DIAG, so that it shows RPM.

When setting the Maximum RPM, adjust the RPM/SITE value so that the Maximum RPM is at or just over the value required. You can also adjust the Minimum RPM setting if necessary (see Pt.1).

The Minimum RPM value becomes the RPM1 site. The RPM step value for each site is shown in the Maximum RPM settings display. If this is 400 RPM, for example, then the RPM2 site will be 400 RPM higher than the Minimum RPM setting. Similarly, the next RPM site will be 400 RPM higher again and so on up to the final RPM site which will be equal to (or slightly higher than) the Maximum RPM value.

You should now have a timing table

. . . continued next page

LK1 should be placed in the settings position when the Hand Controller is subsequently disconnected.

By contrast, the Ignition Coil Driver must be mounted in the engine bay. It can be secured to the chassis using suitable brackets and should be located close to the ignition coil. If you are using a separate MAP sensor, then this can be mounted on the firewall.

Make sure that there is a good connection between the metal cases of both units and chassis. If necessary, you can run separate earth leads to ground (bolt them to the chassis via crimp eyelet connectors).

Once you've made the connections, use your multimeter (set to its ohms range) to confirm that the metal cases are correctly grounded. You should get a reading of zero ohms between each metal case and ground.

Fig.15 in Pt.2 last month shows the external wiring details. Note that all wiring between the Ignition Timing Module and the Ignition Coil Driver should be run using automotive wire and crimp automotive connectors. Similarly, use automotive wire and crimp connectors for the connections to the ignition coil, the +12V supply and to chassis.

The +12V supply should be taken

Plotting The Original Timing Values – Continued

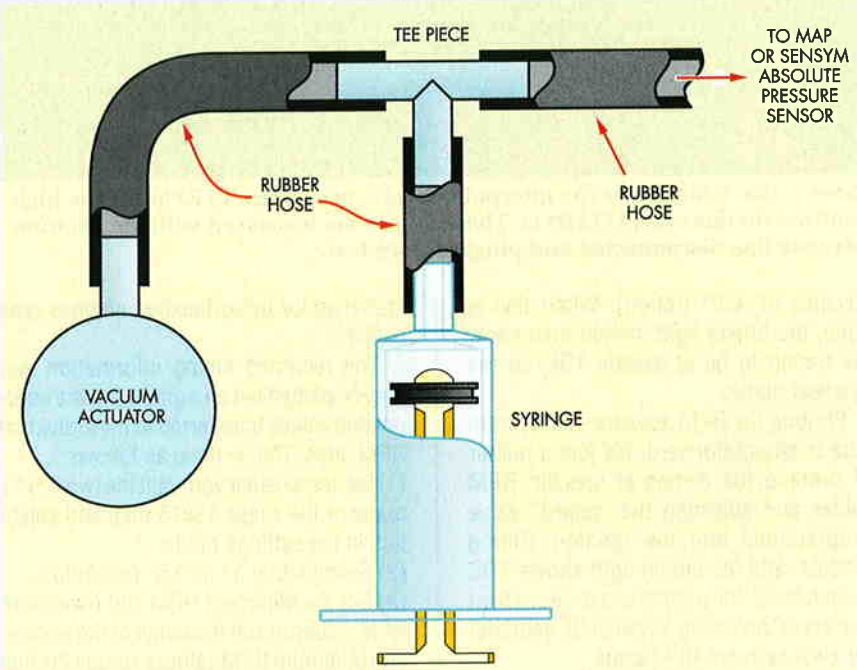


Fig.24: here's how to check the LOAD values in a car with a mechanical vacuum actuator. The syringe is used to vary the pressure.

that is similar to the one shown in Table 1. Note that we have included RPM0 on a different line because it is only there to show that the advance setting remains the same for RPM values below the Minimum RPM site (RPM1).

Finally, you may wish to recheck the advance values assigned to each RPM site. For example, for the table shown, you would recheck the advance at 1000, 1400, 1800, 2200, 2600, 3000, 3400, 3800, 4200, 4600 and 5000 RPM.

Vacuum advance

Having determined the RPM site advance values, you now need to plot the LOAD values.

First, let's assume that you have a car with a mechanical vacuum actuator. In this case, you will need a T-piece in order to connect this existing vacuum actuator (via a hose) to the MAP sensor used with the Programmable Ignition System.

Note, however, that a T-piece is not required if your car is fitted with an existing MAP sensor. In this case, the same signal from the MAP sensor is used both for the existing ignition and for the Ignition Timing Module.

In either case, it will be necessary to feed a MAP sensor signal to the Ignition Timing Module. If you are using the Sensym sensor, then a vacuum hose has to be connected to this.

The T-piece does not have to be anything too complex. You can buy these at an automotive shop or make your own.

As shown in Fig.24, a syringe is used to vary the pressure. However, be careful not introduce excessive pressure into the MAP sensor as it may be damaged.

For 1-bar sensors, the syringe should be pressed all the way in before connecting it to the vacuum hose. That way, you can only "draw" a vacuum by pulling on the syringe plunger (and not increase the pressure). The maximum value is typically around 200 but could be as high as 230 and is equivalent to a 4-4.5V output from the sensor.

If you are using a 2-bar sensor, first check the LOAD value at normal atmospheric air pressure. At 2-bar, this value will be about 100 greater. Do not increase pressure above this increased value (ie, the atmospheric plus 100 value).

In this case (ie, for a 2-bar sensor), the syringe should be inserted into the hose with the plunger set half-way down. If you cannot get a sufficient pressure range with this, then you will have to do the pressure changes in two steps: (1) for vacuum, insert the syringe when the plunger is fully in and draw out the plunger for vacuum; and (2) for boost pressure measurements, insert the syringe nozzle into the hose with the plunger fully drawn and apply boost pressure by pressing on the plunger.

During this process, be sure to always monitor the sensor output level by setting the Hand Controller to DIAG mode (the second line shows the pressure sensor LOAD value). If the value stops increasing as you apply more pressure, then stop immediately. This indicates that you have reached the maximum pressure that the sensor can detect and any further increases could damage it.

Plotting vacuum advance

Let's assume that your car uses a vacuum actuator and you have made the necessary vacuum hose connections using the T-piece. The vacuum advance plot can

from the fusebox. Be sure to choose a connection point that delivers +12V only when the ignition on. In addition, **make sure that this +12V rail DOES NOT drop to 0V when the ignition is switched to START,** otherwise the engine will never start.

In our case, we used twin-core shielded cable to connect between the Ignition Timing Module and an external MAP sensor mounted on the firewall (see photo. Alternatively, you can use automotive cable.

Note that the MAP sensor must be wired with the correct polarity so double-check the wiring and voltages before making the final connection to the this sensor. If you are using an existing MAP sensor, then you won't need to make the supply connections, since these will already be present (see panel on page 73 last month).

A toggle switch will need to be mounted on the dashboard if you want to be able to select between two 11x11 maps. The wires for this are connected to the S1 terminals on the Ignition Timing Module PC board. If you just want one map (either an 11x11 or a 15x15), then switch S1 is unnecessary.

Adjusting VR1

If you are using a reluctor pickup

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now be made at a fixed RPM setting that coincides with an RPM load site value.

However, do not to choose the idle load point because the engine RPM will alter as vacuum advance is applied and you need to be able to adjust the throttle to maintain the fixed RPM setting. Choose the RPM2 site value instead (1400 RPM in our example).

It's now just a matter of plotting the RPM advance against the pressure sensor LOAD reading, as shown on the Hand Controller's display. To vary the LOAD reading, just vary the position of the syringe plunger. Be sure to adjust the throttle to compensate for pressure changes, to maintain engine RPM at the RPM2 site value.

In practice, the vacuum advance value will stop increasing beyond a certain minimum pressure value. This value should be recorded as the minimum load. Similarly, it will also cease changing at a certain maximum pressure value and this should be recorded as the maximum load value. Enter these two values into the Minimum LOAD and Maximum LOAD settings.

Remember that the maximum load value can only be changed by increasing the LOADS/SITE value. In our example below, the LOADS/SITE value is 40 and it ranges from a minimum of 151 (which becomes LOAD1) through to a maximum of 191 (LOAD11).

You can now insert the load timing values into a table as shown in Table 2.

Note that the voltage output from electronic pressure sensors (including MAP sensors) usually decreases with increasing vacuum (lower pressure). This means that the minimum load (maximum vacuum) gives the lowest value on the DIAG display and so this becomes the minimum load site (LOAD1).

If, for some reason, the pressure readings are reversed (ie, the value increases with decreasing vacuum), then the load site numbering will have to be reversed so that the maximum load becomes LOAD1.

		RPM0	Min RPM										Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
Value	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
151	LOAD1			18.5									
155	LOAD2			17.5									
159	LOAD3			16.5									
163	LOAD4			15.5									
167	LOAD5			14.5									
171	LOAD6			13.5									
175	LOAD7			12.5									
179	LOAD8			11.5									
183	LOAD9			10.5									
187	LOAD10			9.5									
191	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 2: the LOAD site values are all made at a fixed RPM setting but do not use the RPM1 value. Choose the RPM2 or RPM3 rev value instead.

		RPM0	Min RPM										Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1	16	16	18.5	21.5	23	25.5	29	32	36	38	42.5	44
	LOAD2	15	15	17.5	20.5	22	24.5	28	31	35	37	41.5	43
	LOAD3	14	14	16.5	19.5	21	23.5	27	30	34	36	40.5	42
	LOAD4	13	13	15.5	18.5	20	22.5	26	29	33	35	39.5	41
	LOAD5	12	12	14.5	17.5	19	21.5	25	28	32	34	38.5	40
	LOAD6	11	11	13.5	16.5	18	20.5	24	27	31	33	37.5	39
	LOAD7	10	10	12.5	15.5	17	19.5	23	26	30	32	36.5	38
	LOAD8	9	9	11.5	14.5	16	18.5	22	25	29	31	35.5	37
	LOAD9	8	8	10.5	13.5	15	17.5	21	24	28	30	34.5	36
	LOAD10	7	7	9.5	12.5	14	16.5	20	23	27	29	33.5	35
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 3: once you've completed Table 2, the rest of the table can be filled in by adding or subtracting the RPM advance steps to the RPM2 LOAD site values. This is the result for a 1988 2-litre Ford Telstar.

This is because the lowest value must be entered as the minimum load site.

Completing the table

Because the vacuum actuator advance system provides the same advance curve at all RPM values, it's quite easy to complete the table. In our example, the advance increases by 1° for each decreasing LOAD site. Table 3 shows the result.

MAP sensor

If your car has an existing MAP sensor, then the load advance will have to be plotted for each RPM site. The table then may not have a consistent change between LOAD sites but its value will be dependent on the ignition mapping.

Programming

The Ignition Timing Module can now be programmed with the timing map. This is done using the VIEW setting, to enable stepping through all the map sites.

Normally, the distributor would be adjusted so that the trigger sensor delivers a firing signal at TDC and the timing map entered on this basis. Alternatively, you can set the distributor to deliver a firing signal at a preset advance or retard value. The entered advance values would need to be adjusted to account for this initial advance or retard setting of the distributor.

Make sure that the distributor's rotor is still within its range for firing with the values set in the programmable ignition. If you do not change the settings much beyond the original ignition timing curve, then the rotor will remain within range to allow the spark to bridge the gap within the distributor cap to fire the spark plugs.

Finally, don't forget to set the interpolation back to "on" after plotting the ignition timing.

to trigger the Ignition Timing Module, the first thing to do is to adjust trimpot VR1. That's done as set out in the accompanying panel headed "Plotting The Original Ignition Timing Values" (see text immediately following "Reluctor adjustment").

If you have plotted the RPM advance curve (see panel), then most of the parameters within the Ignition Timing Module will have already been set. You will, however, need to set the dwell for the ignition coil.

Conversely, if none of the parameters have been set, then you will have to start from scratch. The various settings were detailed in the first article in March 2007.

The first step is to place jumper LK1 in the settings position. That done, set the number of cylinders for your car, then set the edge sense to high (or to low if you know it should be this setting). The diagnostic setting should then be checked to ensure it is set for "interpolation on".

Next, decide whether you want the two 11x11 maps or the single 15x15 map and select this in the map setting. Follow this step by selecting either the 1° or 0.5° resolution and set the debounce to 0.4ms.

Note that the latter may need to be

Using An Existing Coil Driver Module

IN SOME CASES, it may be possible for the output from the Ignition Timing Module to drive an existing ignition module (or coil driver) instead of using the SILICON CHIP Ignition Coil Driver.

There are a few things to sort out before doing this, however. First, you must find out the voltage sense used for the trigger signal. This can easily be determined if the trigger signal is produced by the ECU. For other triggers, the sense may need to be determined by trial and error.

Initially, you should set the Ignition Timing Module's EDGE setting set to LOW. If it doesn't work, try reducing the 470Ω output resistor in the Ignition Timing Module to 220Ω in order to drive the original coil driver module.

If it still doesn't work, try changing the EDGE setting to HIGH. In addition, the Ignition Timing Module output must be inverted for positive edge firing by taking the drive from transistor Q4 – see Fig.14 in last month's article.

ECU trigger signal

What if you are using the trigger signal from an existing ECU (or engine management unit)?

In this case, the output may normally be at +5V, with a low signal then applied to the ignition module to "charge" the coil and a high-going signal subsequently used to fire a plug. Alternatively, the signal sense could be completely reverse to this.

Generally, it's easy to determine the voltage sense by measuring the voltage from the ECU when the engine is idling, using a multimeter set to read DC. The meter will show the average voltage of the trigger signal and so a normally low output will give a voltage below 2.5V and a normally high output will give a voltage above 2.5V.

If the measured voltage is less than +2.5V, then the plugs fire on the low-going signal edges (ie, the ECU's output goes to +5V to "charge" the coil). In this case, the EDGE setting in the Ignition Timing Module should be set to LOW.

Conversely, if the voltage is greater than +2.5V, it means that the coil charges when the ECU output goes to 0V and the plugs fire on the high-going signal edges. In this case, the EDGE setting in the Ignition Timing Module should be set to HIGH. In addition, the signal output from the Ignition Timing Module must be inverted (by taking the output from transistor Q4), as shown last month in Fig.14.

set to 2ms if there are problems. This higher debounce period is usually required only for points triggers.

Dwell setting

Now for the dwell setting. First, attach an *external* spark plug to the HT lead from the coil and connect the plug's metal thread to chassis (ground). You can use a heavy-duty lead with alligator clips at either end to make this connection.

Now set the dwell to 0ms and set the internal oscillator in the Ignition Timing Module to on. That done, increase the dwell until the spark plug appears to give its best spark.

Note that the dwell value will not change until the Up switch on the Hand Controller is released, so be sure to release the switch each time you make a change. Stop increasing the dwell when the spark appears to have reached its maximum intensity.

Once you've finished, switch off the ignition and reconnect the HT lead correctly so that the car will run. The internal oscillator will automatically be off when power is re-applied.

MAP sensor & RPM ranges

If you intend using the unit as an interceptor (ie, to modify the timing output from an existing system), then you will need to know both the existing pressure (MAP) sensor and RPM ranges. This means that the Ignition Timing Module should be set up so that it initially makes no changes made to the timing.

The range over which the existing MAP sensor works can be found by monitoring the LOAD value in the DIAG display mode. First, record the maximum load value by checking the LOAD reading with the ignition on but without the engine started. This should be done only for normally aspirated engines when the barometer shows 1013hPa of atmospheric pressure (ie, the standard pressure at sea level).

If you are at a higher altitude, then add another 3% to the reading for every 300m above sea level to compensate for the loss in air pressure. Alternatively, vary the reading by the percentage that your local air pressure differs from 1013hPa. Increase the reading for lower air pressure and decrease it for higher air pressure.

For turbo engines, the maximum reading from the pressure sensor is found at maximum boost.

The minimum load value can be found by driving the car downhill, with the engine being overrun (eg, by shifting to a lower gear than normal). Note, however, that some cars tap the vacuum line for the vacuum measurement before the butterfly valve that's located within the air inlet throat. In this case, vacuum measurement is not available on a fully-closed throttle because the butterfly valve is also closed. What's more, just slightly opening the throttle in this case will cause the vacuum to reappear.

Once you've measured the minimum load value, enter it into the settings as the Minimum LOAD. That done, enter the Maximum LOAD by altering the loads/site value so that it is equal to or a little over the value previously measured.

You now need to set the minimum and maximum RPM values to suit the range of the engine. Just set the Minimum RPM value to the idle speed and the Maximum RPM value to the engine red line.

Note that the idle speed can be measured using the Programmable Ignition System, with the display set to DIAG to show the RPM.

When setting the Maximum RPM, adjust the RPM/SITE value so that the maximum RPM is at or just over the value required. You can also adjust the minimum RPM setting to achieve the best compromise for the adjustment.

Testing

The Programmable Ignition System should now be ready for it first real test. If you are using it as an interceptor, make sure that all the initial timing map values are zero. You can ensure this by pressing the Reset button on the Hand Controller and waiting one second so that RESET is shown on the display. This will clear all the timing values to zero but only for the map selected.

If you want to clear both the alpha and beta maps, then you will need to use switch S1 to select the alternative

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Disabling Original Ignition Systems

IF YOUR CAR already has a fully electronic ignition, it can be disabled quite easily. Just disconnect the trigger sensor from the existing ignition and connect it to the Ignition Timing Module instead.

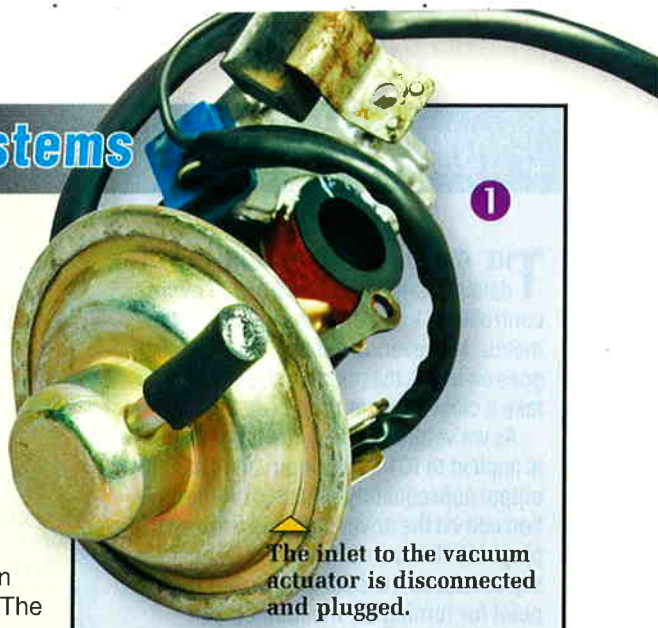
Note that with some ignition systems, you will not be able to find a suitable trigger signal that does not also include timing information. In this case, you can only use the Programmable Ignition System as an interceptor.

To disable a mechanical advance system, you first need to remove and disassemble part of the distributor. Make sure you turn the engine to TDC for cylinder 1 before removing the distributor.

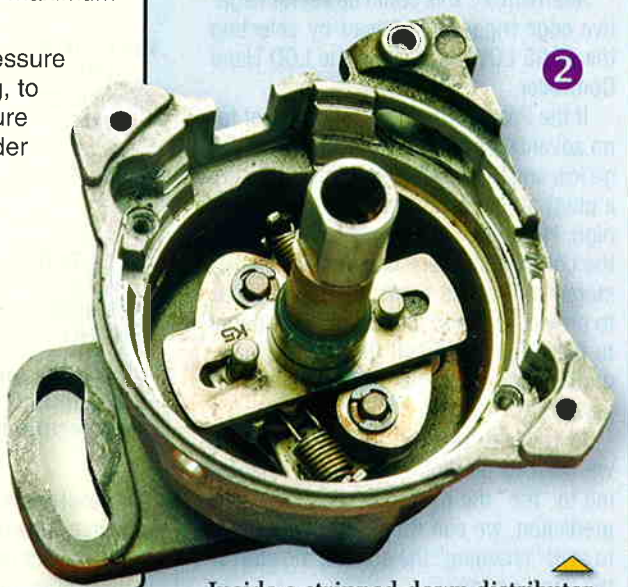
The distributor must be stripped down to give access to the mechanical weights, so they can be locked in place. We used an aluminium plate to lock the weights to the minimum advance position. The vacuum actuator hose is disconnected (to set the advance to the maximum load setting) and the inlet to the actuator is plugged.

The vacuum hose is then connected to the manifold pressure sensor that's used with the Programmable Ignition System (eg, to an external MAP sensor or the on-board Sensym sensor). Be sure to reinstall the distributor with its rotor pointing towards the cylinder 1 high-tension terminal on the distributor cap.

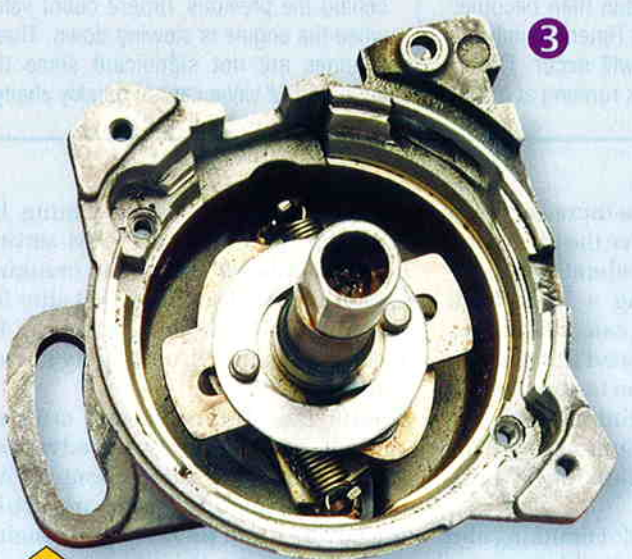
Left: you can use a simple aluminium plate like this to lock the mechanical timing weights inside a distributor. It simply slides over the distributor cam and the timing weight posts, as shown in the photos.



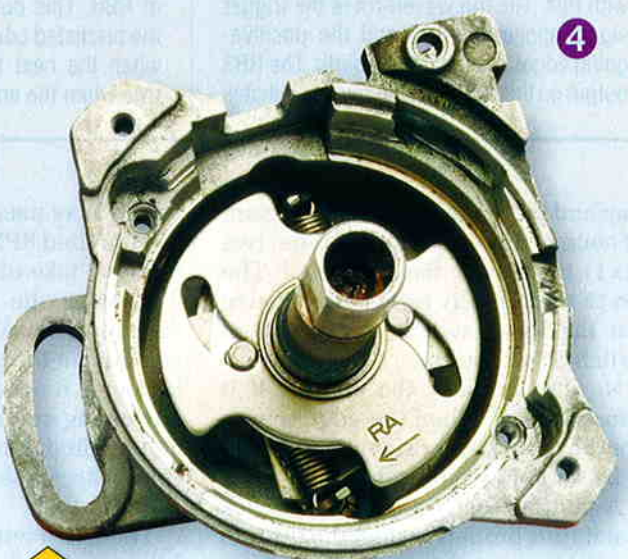
The inlet to the vacuum actuator is disconnected and plugged.



Inside a stripped-down distributor, showing the timing weight posts.



The aluminium plate prevents the posts attached to the weights from sliding in their slots as the RPM increases, thus locking them in position.



The partially reassembled distributor with the advance plate back in position. Because the weights are locked, the advance plate is now also locked.

Programmable Ignition Software: How It Works

THE CIRCUIT DESCRIPTION in Pt.1 details many of the functions of microcontroller IC1 and explains its pin assignments. However, it doesn't explain what goes on inside the microcontroller, so let's take a closer look at this.

As we've already seen, the trigger signal is applied to IC1's RB0 input and the RB3 output subsequently switches off the ignition coil via the driver circuit to fire a spark plug. We'll assume here that a positive signal edge at the RB0 input is the trigger point for turning off the ignition coil.

Alternatively, this could be set for negative edge triggering instead by selecting the EDGE LOW setting via the LCD Hand Controller.

If the Programmable Ignition is set for no advance or retard, the RB3 output will go low and turn off the ignition coil (to fire a plug) at the instant the RB0 input goes high. However, we also need to "charge" the coil so that there is sufficient energy stored in it at the point of "firing" so as to provide a spark. The duration required to fully charge the coil (to provide maximum spark energy) is called the "dwell" period.

In order to provide this dwell period, we need to predict when the coil is going to "fire" the next plug. Based on this prediction, we can then determine when to start "charging" the coil (ie, the start of the dwell period).

Fig.25 shows the waveforms associated with this. The top waveform is the trigger signal applied to RB0 and the positive-going edges are the firing points. The RB3 output on the waveform below this initiates the dwell period before firing occurs at the positive edge of RB0.

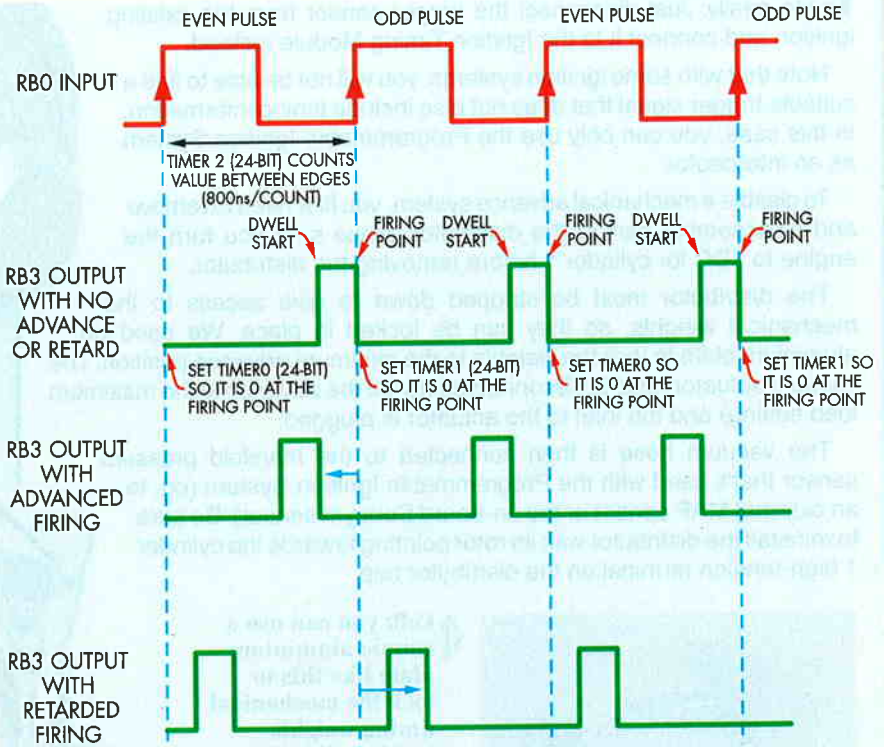

EVEN PULSE
ODD PULSE
EVEN PULSE
ODD PULSE
RB0 INPUT
TIMER 2 (24-BIT) COUNTS VALUE BETWEEN EDGES (800ns/COUNT)
DWELL START
FIRING POINT
DWELL START
FIRING POINT
DWELL START
FIRING POINT
RB3 OUTPUT WITH NO ADVANCE OR RETARD
SET TIMER0 (24-BIT) SO IT IS 0 AT THE FIRING POINT
SET TIMER1 (24-BIT) SO IT IS 0 AT THE FIRING POINT
SET TIMER0 SO IT IS 0 AT THE FIRING POINT
SET TIMER1 SO IT IS 0 AT THE FIRING POINT
RB3 OUTPUT WITH ADVANCED FIRING
RB3 OUTPUT WITH RETARDED FIRING

Fig.25: the top waveform in red represents the trigger signal applied to the RB0 input of the microcontroller in the Ignition Timing Module. The green waveforms show the three possible RB3 output signal conditions.

To predict the next firing point, we use a timer (Timer2) that counts up by one for each 800ns between the positive edges of RB0. This count value then becomes the predicted count for Timer2 to indicate when the next firing will occur. This is true when the engine is running at a constant RPM. However, when the engine is increasing in speed, the firing point will occur somewhat earlier than the previous Timer2 count value.

Conversely, the firing point will lag behind the previous Timer2 count value when the engine is slowing down. These changes are not significant since the engine RPM value cannot quickly change

map and press the Reset button again. Of course, this only applies if the two 11x11 maps have been selected. The 15x15 map is fully reset to zero using just the Reset switch, regardless of switch S1's position.

Now try to start the engine. If it refuses to start, then the edge setting (for the input trigger signal) may need to be set to low rather than high.

Assuming that it does start, check that it runs properly when the throttle is quickly pressed to increase the revs. If it falters, then the dwell period may need increasing a little. Additionally, the response to the low-speed RPM setting may need to be increased by a few hundred RPM above the idle speed for best "take-off" acceleration.

Altering the timing a little from its standard setting can sometimes smooth out the idle speed if it tends to be rough. It needs to be tested by both advancing and retarding the existing value to find the optimum setting. This setting becomes the cranking advance as well.

These two settings (for cranking and idle) may not be compatible because the idle advance setting may make the engine hard to start. If necessary, the cranking timing can be made independent of the idle timing by lowering the minimum RPM setting to below idle but above the cranking speed. This will set the RPM1 sites for cranking only. Cranking RPM can be measured on the DIAG display during starting.

Both the off-throttle and cruising settings can generally be advanced further to improve fuel economy. However, too much off-throttle and cruising advance can produce poor engine response if extra throttle is suddenly applied for acceleration.

Any pinging (detonation) problems at high loads can be solved by reduc-

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to any extent between successive input trigger signals.

The dwell period can be initiated before the next firing by doing some calculations using the Timer2 count value. If, for example, the required dwell for the coil is 4ms, we can calculate that this period is equal to a count of 5000. This is because 4ms requires counting 5000 of the 800ns count periods. We can then start the dwell at a count of 5000 before the next expected firing point.

Initiating the dwell start and switching off the coil to fire a plug requires another counter. At every positive signal edge on RB0, this second counter (Timer0) is set at a value so that it will reach a count of zero at the next expected firing position. Before it reaches zero, the counter is checked every 204.8µs to see if it has reached the value to start the dwell period. If this value has been reached, RB3 goes high and remains high until the counter reaches zero, at which point RB3 goes low to fire the plug.

In order to advance or retard the firing point, instead of setting Timer0 to fire at the next expected RB0 positive edge we either fire before this for advance or later than this for retard. The dwell is also shifted to start earlier as the timing advances or later as the timing retards.

We need to make some calculations in order to set Timer0 to a value that will give the correct amount of advance or retard in degrees. As we know, the Timer2 value provides us with the count between firing pulses. Firing pulses occur twice per engine revolution for a 4-cylinder 4-stroke engine and three times per engine revolution for a 6-cylinder 4-stroke. So for a 4-cylinder 4-stroke engine, we divide the Timer2 count by 180 because plug firings are 180° apart, with two pulses per 360° engine revolution. This gives us the count per degree.

For the 0.5° resolution setting, we divide by 360 instead of 180 to get the number of counts per 0.5°. Similarly, for a 6-cylinder engine, we divide by 120 for the 1° resolution setting because there are three firing pulses per 360° engine revolution. The number of degrees of advance or retard required is then multiplied by the count per degree value. This is then either added to the Timer2 value to retard the timing or subtracted from the Timer2 value to advance the timing.

Timer0 is then set so that it reaches a count of zero at this altered Timer2 value. In this way, RB3 is controlled by Timer0 to set the dwell and fire a plug (when Timer0 is zero) at the required advance or retard setting.

Well, that's basically how the system works but in practice it's a bit more complicated that that. In reality, there are two timers: Timer0 and Timer1. Timer0 is used to decide when to drive RB3 high (for the dwell) and low (to fire the plug) between each of the even-numbered positive edges from RB0.

By contrast, Timer1 is used to drive RB3 high and low between each of the odd-numbered RB0 positive edges.

The reason we need two timers is because one of them might still be in use, determining when to drive RB3, when the next positive edge from RB0 occurs. If only one timer was used, it could not be made ready for the next firing sequence, as this would affect the current firing position. The only alternative is to use two timers, as described.

Note that the firing point is calculated from the previous RB0 positive edge and may not exactly match the current RB0 edge when there is no advance or retard adjustment. This can happen when the engine revs are changing.

In this case, we fire the coil when the RB0 output goes high. In addition, when the timing is set to retard, the firing point is recalculated when the next RB0 positive edge occurs. If the timing is set to advance, the plug will also be fired at the positive RB0 edge if it has not already fired.

Another calculation made within the microcontroller is for the engine RPM value. This calculation first divides the Timer2 count value by 16 and the result is then divided into 93,750/cylinder for a 4-stroke engine. The result is a value for the number of "100 RPM" increments.

For example, lets assume that Timer2 has a count of 37,500 and we are running a 4-cylinder engine. The 37,500 is then divided by 16 to give a result of 2343. Dividing this value into 93,750/4 gives a value of 10. This is the number of "100 RPM" increments which in this case is equivalent to 1000 RPM.

This calculation is correct because with a Timer2 count of 37,500, the period between pulses is 30ms because each count represents 800ns (800ns x 37,500 = 30ms). A 30ms period is 33.333Hz or 2000 pulses per minute. Since the engine is a 4-cylinder 4-stroke, there are two pulses per revolution and so the engine speed is 1000 RPM.

Calculations are also required to convert the RPM and pressure sensor values to site values. These calculations are based on the size of the map selected (11x11 or 15x15) and the minimum and maximum RPM and load values. Further calculations perform the interpolations for the advance and retard values between both the RPM and load sites.

ing the advance. Note that with the 11x11 map, there are 121 individual adjustments that can be made at the various RPM and engine LOAD sites. You will probably not need to alter too many of these. Just adjust those sites that need to be changed to eliminate pinging (reduce the timing value) or to provide more power under load (increase the timing value).

In practice, the vehicle can be driven with the Hand Controller connected if you wish to fine-tune the adjustments (get someone else to do the driving). However, it's important to note that the Programmable Ignition will work best when the Hand Controller is in the settings mode, as selected using link LK1 on the Ignition Timing Module.

The microcontroller then does not spend time updating the LCD module and this allows its program to be solely devoted to updating the timing. As a result, any responses to manifold pressure changes and RPM changes will not be hampered by display updates.

The Hand Controller can be disconnected when all the settings have been entered. **Note that it should only be connected or disconnected with the power to the Ignition Timing Module switched off.** SC

Corrections

(1) The 4.7kΩ resistor shown to the right of REG1 in Figs.8-13 last month should be 47kΩ.

(2) The 10kΩ resistor shown immediately to the right of VR1 in Fig.10 should be 47kΩ.

(3) The resistor immediately to the right of Q4 in Figs.8-13 is 47kΩ.

(4) The parts list should show 3 x 100nF MKT polyester capacitors (not 1). A 10µF 16V PC electrolytic capacitor should also be added to the list.

Improving stability & adding a serial port

GPS-Based Frequency Reference Circuit Mods & Additions

The short term frequency stability of the GPS-Based Frequency Reference described in the March and April issues can be improved with some circuit changes, as described here. It's also quite easy to add an RS-232C serial output, so the NMEA data stream from the GPS receiver module can be fed out to a PC for other purposes.

By JIM ROWE

A FEW DAYS after the March issue of SILICON CHIP had been published with the first article describing the GPS-Based Frequency Reference, an email arrived from New Zealand reader Dr Bruce Griffiths advising that the method used for cascading the synchronous frequency dividers IC4, IC5 and IC6 was not the best way. Correcting this would improve the divider's reliability and hence the short-term frequency stability.

After studying the data, it turned out that Dr Griffiths was correct. As a result, I performed some "surgery" on the prototype reference, changing the divider configuration over to one which should give more reliable synchronous division. Then I set it up again and let it run for a few days, while I monitored its operation.

Sure enough the short-term stability did seem to be better, although not dramatically so. The benefits were mainly in terms of reduced jitter in the "raw" PLL error correction voltage, before filtering.

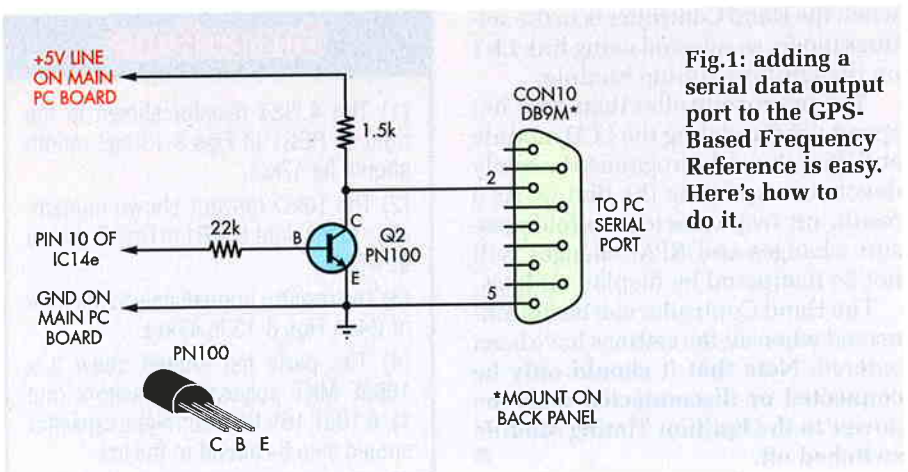

Fig.1: adding a serial data output port to the GPS-Based Frequency Reference is easy. Here's how to do it.

New PC board

Now while it's not too difficult to change the configuration on the original PC board by cutting tracks and soldering in short insulated wires underneath, I have revised the board design so that the job will be even easier if you get a board etched with the new pattern. These should be available from board manufacturers shortly.

The revised divider circuit configuration is shown in Fig.2. The 10MHz clock signals coming from the crystal oscillator via buffer IC3c are now fed directly to the clock inputs (CP pins 2) of IC5 as well as IC4, and also to the clock inputs of IC6 (pins 1 & 5) via inverter IC3e. The inverter is needed because the flipflops in IC6 are negative edge triggered, while IC4 and IC5 are positive edge triggered.

The TC (terminal count) output of IC4 now feeds into the CET (clock enable) input of IC5, to ensure more reliable synchronous count cascading, while the TC output of IC5 is also fed to the J and K inputs of IC6a and IC6b (pins 14, 3, 7 & 10) for the same reason. As a result, the complete synchronous division process down to 50kHz should now be significantly more reliable.

Fig.3 shows how the revised main PC board is wired for this section of the circuit. The changes are all at the front righthand corner of the PC board, just behind CON1 and CON2.

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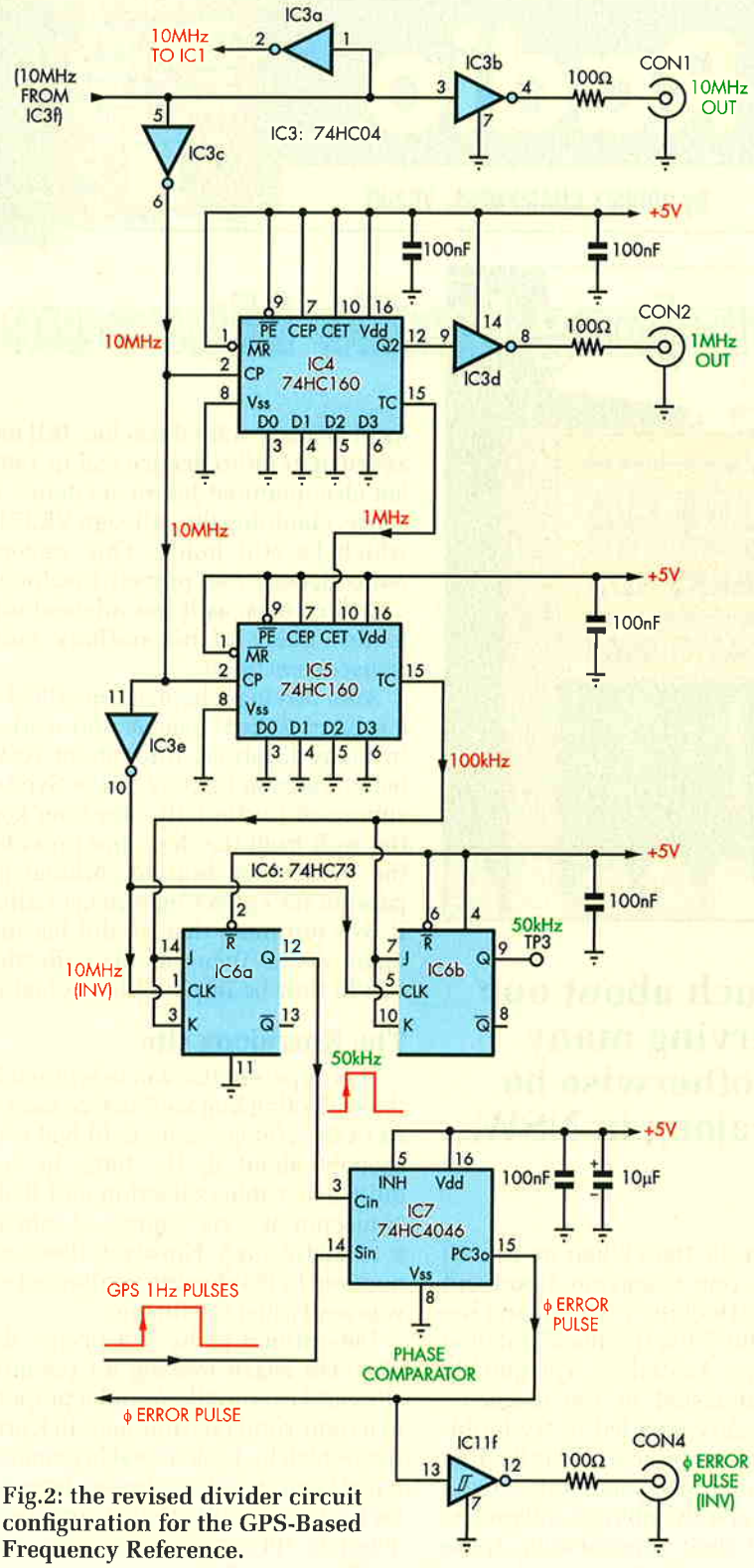


Fig.2: the revised divider circuit configuration for the GPS-Based Frequency Reference.

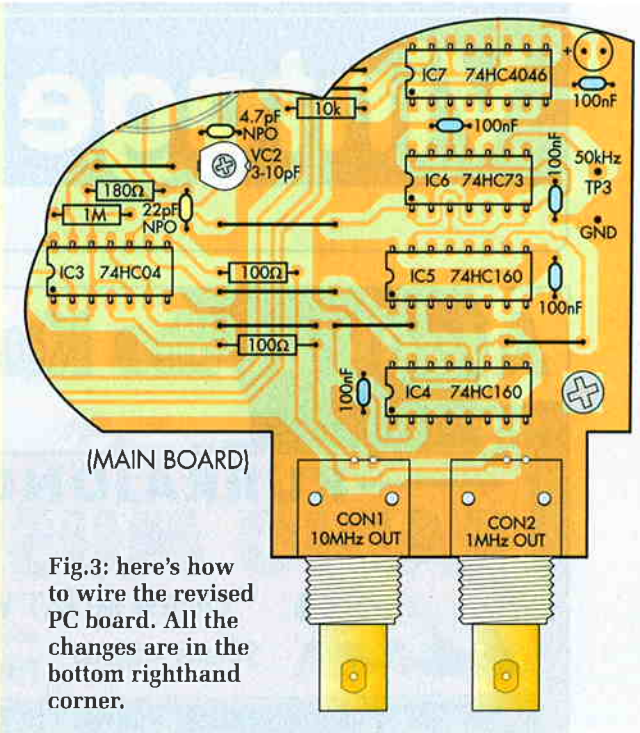


Fig.3: here's how to wire the revised PC board. All the changes are in the bottom righthand corner.

Wiring up the new divider configuration should be very easy if you use this diagram as a guide, instead of the corresponding section of the original overlay diagram. The same diagram should also help you if you're making the change by operating on the original board.

Want to add a serial port?

A couple of other readers sent emails asking how easy it would be to add a serial data output port to the GPS-Based Frequency Reference, so that the NMEA data stream coming from the GPS receiver module could be fed out to a PC – for synchronising real-time clocks and other purposes.

As it happens, adding such a port is very easy. All that's needed is to mount a DB9M connector on the rear panel in a suitable spot (say above CON3 and CON4) and connect it to the main board via the simple inverting buffer circuit shown in Fig.1. As you can see, this involves only two resistors and one PN100 transistor, so it could be wired on a postage-stamp sized piece of matrix board and supported on the back of the DB9M connector by the wiring.

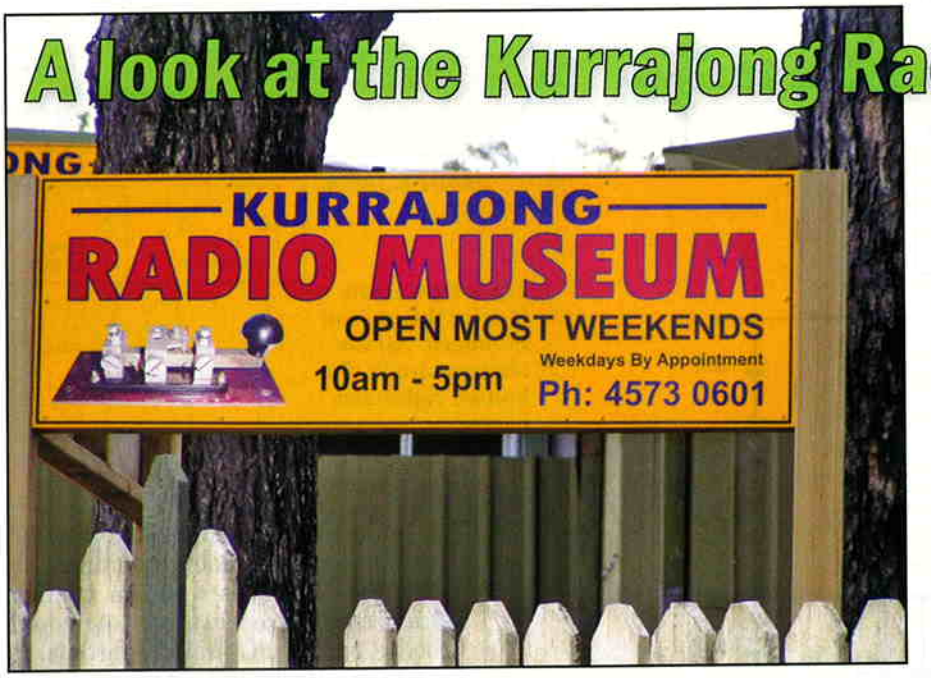
There are only three connections to be made between this serial port circuit and the main PC board: one for the ground connection, one for the +5V line and the third for the buffered RS-232C GPS receiver's data stream available from the output of IC14e (pin 10). This last signal is also conveniently available via the wire link on the top of the main board, just to the rear of IC8 and its 100nF supply bypass capacitor (one of the two links just to the front of CON7).

So if you want to add a serial output port to the Frequency Reference to make the GPS data stream available for external use, that's how to do it. **SC**

Vintage Radio

By RODNEY CHAMPNESS, VK3UG

A look at the Kurrajong Radio Museum



Radio museums can tell us much about our radio history, as well as preserving many worthwhile items that would otherwise be lost. One of the best is at Kurrajong in NSW, just west of Sydney.

MUSEUMS CAN BE DUSTY, uninteresting places, particularly if the people running them know little about the exhibits and the presentation is poor. But that's not the case with a vintage radio museum I recently visited in Kurrajong, NSW. It was run by an enthusiast named Ian O'Toole and is one of the best I've seen.

How it started

The start of this museum goes back many years. Ian's father owned a newsagency in Newcastle in the 1950s and 60s and Ian had the job of helping his father with the magazine returns. This is a boring job which involves returning either the front covers or the headings of magazines and newspapers for credit on the unsold items.

However, in 1955 when he was 10 years old, one magazine stood out – "Radio & Hobbies", which later became "Radio, TV & Hobbies" and then "Electronics Australia". He quickly became interested in the magazine and eventually decided to try building some of the projects described. In fact, I wonder how many other radio enthusiasts (both hobbyist and professional) got their introduction to the radio field through "Radio & Hobbies"? I know I did.

To start off, a semi-complete crystal set was purchased for ten shillings ($1) in 1955. And that was to be the start of a lifetime interest in radio and vintage radio equipment.

Ian was fortunate to have a mentor for his radio interests in Bill Munn, a local primary school teacher. Bill had an amateur radio licence and in 1967, Ian also qualified for an amateur's licence, obtaining the call-sign VK2ZIO which he still holds. This amateur radio licence has proved invaluable over the years, as it has allowed him to test many of his military radio transceivers on-air.

After leaving school, Ian qualified as a primary school teacher and worked in many locations throughout NSW, before retiring in 2002 to the Sydney suburb of Castle Hill. Teaching kept the wolf from the door and provided the money for him to indulge his passion for collecting vintage radios. It was fortunate that he did because many of the items in his collection would now be impossible to obtain.

The Kurrajong site

It is apparent that Ian was bitten by the collecting bug well before most of us in the vintage radio field had even thought about it. By 2002, he had quite a sizeable collection and had a "museum of sorts" squeezed into a 5 x 11-metre shed. However, there was no room to display the equipment – it was really just in storage.

Determined to have a proper display, Ian began looking for potential sites and eventually found a property in a semi-rural environment in Kurrajong which had considerable potential. It had been an old mushroom farm and had a large modern shed measuring about 24.4m long by 9.2m wide, with walls 6.1m high.

There were also two houses joined together and a second, older shed roughly the same size as the new shed. In addition, there were numerous other sheds of varying sizes, so this place really was "shed heaven" – ideal for the museum. The location wasn't too far out in the sticks, being at the

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This section of the museum displays domestic radios from 1927 onwards. Pre-1927 radios are displayed separately.

foothills of the Blue Mountains, which meant Sydney residents could visit the museum when it opened.

The height of the new shed wasn't a problem, as Ian intended to install a mezzanine floor. The museum would then be housed on this upper floor, while the bottom floor would be used for storing radios and other material, and for mechanical restoration work. However, the museum would not take up the entire upper floor, as three rooms would be added to house a workshop/repair area (for electronics only), a broadcast studio and a room devoted to AWA equipment.

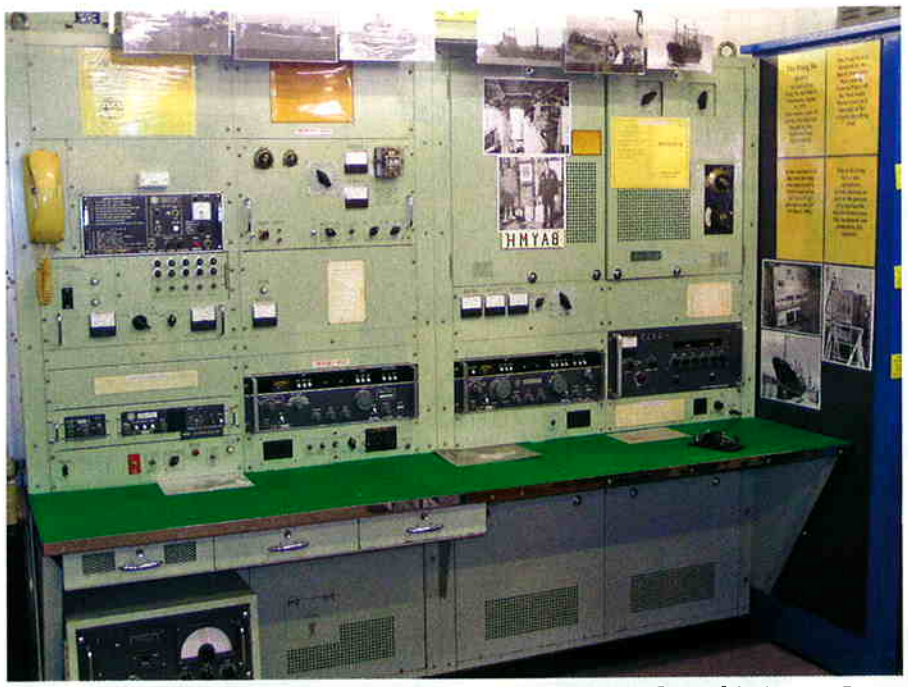
Because the block is reasonably steep, the mezzanine floor entrance would be at ground level (following suitable earth works). Once the museum building was nearing completion, a demountable classroom was brought on site. This was fitted out as the entrance, toilet block and shop, with tables and chairs so visitors could sip coffee or tea and relax.

These World War 2 military radios were built by Astor Radio Corporation in Melbourne, Victoria.

700 items

Ian now had room to effectively display 700 major items of radio history, while many other lesser items could be stored on the bottom floor, below the museum.

It took Ian and his wife Patricia about six weeks and two trailer loads a day to shift all the items. Those items intended for the museum were put into a separate shed and at the end of six weeks, the doors could hardly be closed! The equipment was then gradually sorted and eventually



This is the radio station salvaged from the North Korean "drug ship" Pong Su. The ship was used subsequently by the RAAF for target practice.

This section of the museum houses a selection of World War 2 era "walkie talkies" and backpack radios.

brought back for assembly in the museum building.

According to Ian, this process took them around three years from start to finish and they received lots of valuable help from some very good amateur radio friends.

Laying it out

Once the museum shell was finished, everything had to be laid out in a logical fashion. This also involved carefully planning the electrical wiring, as well as the many cables that would be necessary to connect antennas and audio lines, etc.

Ian's career as a primary school teacher proved invaluable in the design of the museum. As well as displaying lots of interesting equipment, it had to tell a story and be of interest to all ages.

Over a period of many months, Ian set up the equipment and displays, along with yellow information cards. Antennas were vitally important too, otherwise on-air displays would be a dismal failure. Ian installed antennas to cover various frequency ranges, along with broadband amplifiers to provide enough signal for most of the receivers.

The accompanying photographs show the wide variety of equipment on display. One area of particular interest is the Morse code training area, where people can try their hand at Morse code. The 12 listening posts are also interesting. These provide aural history lessons via pre-recorded information on CDs as follows:

- Old radio serial introductions.
- Old radio advertisements.
- A radio history channel.
- Morse recorded off air (this goes to the two Morse training positions).
- A time and frequency channel (time signals from WWVH, Hawaii).
- An aircraft channel – where aircraft flying the Pacific can be heard.
- A School of the Air channel – listen to lessons as they happened.
- A maritime channel – weather forecasts for shipping.
- An international broadcast channel featuring the 1950s & 1960s.
- Radio amateurs talking about radio restorations.
- Amateur Radio NSW weekly broadcast
- The VKS737 Outback Radio channel – hear travellers in outback Australia.

Opening day

It's all very well to have a first-class museum but if no-one knows about it there will be no visitors. Fortunately, Ian is a bit of a PR man and had been extolling the virtues of his new museum for some time, particularly to amateur radio operators and to members of the Historical Radio Society of Australia (HRSA), to name but a few groups.

It is always a smart move to get a well-known dignitary to open such a facility and Ian engaged the local Mayor of Hawkesbury City Council, Bart Basset, to do the honours. Bart is

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a helicopter pilot and had a particular interest in the operational aviation radios on the day.

The opening ceremony was held on Saturday 27th May 2006, with the museum officially opening to the public on Sunday 4th June 2006. Working closely with the council was important as they are able to help publicise the museum through their tourist information centre.

The Pong Su

So who or what was the "Pong Su"? Well, as you may remember, the Pong Su was a 3743-tonne North Korean freighter that was observed anchored in Australian waters off Lorne, Victoria on the night of April 15, 2003. Australian Federal Police observed the vessel and followed two suspects who appeared to have come from the ship. They were apprehended and found with 50kg of heroin in their possession.

Ultimately, a total of 125kg of heroin was found and Australian authorities ordered the ship into harbour. The ship then endeavoured to escape into international waters and a 4-day chase ensued. It ended when Australian Army Special Operations Forces boarded the ship from a helicopter and seized control.

The ship was subsequently brought into Sydney harbour and the crew arrested. After all the legal action had been taken, the ship was stripped, towed out to sea and sunk by RAAF F-111 aircraft on 23rd March 2006.

So what has this to do with Ian's museum? Quite a bit actually! Ian was able to secure the radio station from the Pong Su and it now forms the biggest single display in the museum. Not many people have the opportunity to see the radio station from a large ship, as they are normally out of bounds to passengers.

This particular radio station was manufactured by the Japanese company Anritsu in 1980. It weighs close to 800kg and can basically be divided into two sections. The lefthand side contains the mandatory emergency equipment and is capable of being powered by the ship's 24V batteries. This equipment includes an emergency transmitter and a receiver for low-power communication on the MF and HF marine bands, along with a 500kHz Auto Alarm receiver.

The righthand side of the station contains the main receiver and transmitter. These were powered from the ship's supply, with 100V AC for the receiver and transmitter frequency synthesiser and 440V AC 3-phase for the power amplifier. The latter uses a pair of 4CX250Bs as the output valves and these deliver 500W CW (Morse) on MF and HF.

Ian could find no indication that the transmitter was used on any mode other than CW (HF) and MCW (MF). He says there is a lot of circuitry in the frequency synthesiser so there may be provision for SSB, although it certainly hasn't been utilised in this particular installation.

Both receivers are operational and cover 100kHz to 34MHz. The transmitters cover the 400-515kHz, 2MHz, 4MHz, 6MHz, 8MHz, 12MHz, 16MHz, 22MHz & 25MHz marine bands.

Unfortunately, the VHF (156MHz) and radio direction finding (DF) equip-

Rack alley – an impressive collection of the equipment used by radio stations.

This history board has lots of information on the era preceding 1930, together with scrapbooks containing press clippings on radio station 2WS (1224kHz).

Ian O'Toole taking delivery of the 1961 AWA 500W transmitters for his museum.

Vintage cars visiting vintage radios at the Kurrajong Radio Museum.

ment had "disappeared" before Ian obtained the station. However, he does have the ship's PA system, which has its own tuner and tape recorder, plus a cassette with a CW practice session (the ship's engines can be heard running in the background).

A quick tour

So much for the specialist areas. Let's now take a quick look at the rest of the museum.

First, there is a 1940 Palmavox Console Radio, which plays the Argonaut's theme. Then there's the 1926 crystal set, which astounds people with its quality. There are also many reel-to-reel tape recorders ready to be demonstrated, along with cartridge machines and cassette players.

The working radio studio control room is quite an experience; there are 10 display boards illustrating radio history from the very beginning until the end of WW2; there's a special room for the AWA Company and it's products; there is a 12-minute video "AWA and the War"; there are operational teleprinters; and there is a long wall of armed service/professional radios.

A special display shows the history of domestic radios. There is also a display of WW2 spy radios (I'd be particularly interested in these). In short, there is a vast array of radio equipment on display and it continues to grow.

The shop

The shop not only provides light refreshments to visiting groups (by arrangement) but also sells DVDs, CDs and some books. There are also some small curios, including FT243 crystal cases and metal 6H6 valves mounted on wooden bases.

Where is it?

The Kurrajong Radio Museum is located at 842 Bell's Line of Road, Kurrajong Hills, 2758. If you are approaching from Sydney, you will have to cross the Hawkesbury River at North

AWA CR6 & Kingsley AR7 HF aviation receivers.

Scouts tune in at the listening booths.

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Photo Gallery: Gladiola 1932 TRF Receiver

THE GLADIOLA COMPANY OF ADELAIDE was one of Australia's smaller radio manufacturers. The set shown here is a 3-valve TRF receiver and was manufactured in 1932. It was housed in an upright wooden cabinet and used the following valve types: 57 detector, 2A5 audio output and 80 rectifier. Photo: Historical Radio Society of Australia, Inc.

Richmond. As you come off the bridge the museum is 8.42km ahead on the righthand side of the road, between Kurrajong and Kurrajong Heights (look for the Kurrajong Radio Museum signs on the property).

If you want more precise instructions, visit their web page at **www.vk2bv.org/museum/** or just enter "Kurrajong Radio Museum" into the Google search engine. The museum is usually open on Saturdays and Sundays from 10am to 5pm and at other times by special arrangement. The cost is $10 per adult and $5 per child.

Summary

The Kurrajong Radio Museum does an excellent job when it comes to displaying and preserving many important aspects of our vintage radio heritage.

However, Ian is always on the lookout for more items that may be suitable for the museum. In fact, he has just recently obtained two broadcast-band 500W transmitters (circa 1961) and these are shown together in one of the photos, loaded onto his trailer before transport to the museum. He only needs a large antenna to go with them and he will have a complete broadcasting station!

In short, Ian and Patricia O'Toole's museum is a welcome addition to the local Hawkesbury area as a tourist attraction and an educational facility. It's much more than just a collection of old radios and is well worth seeing and supporting. **SC**

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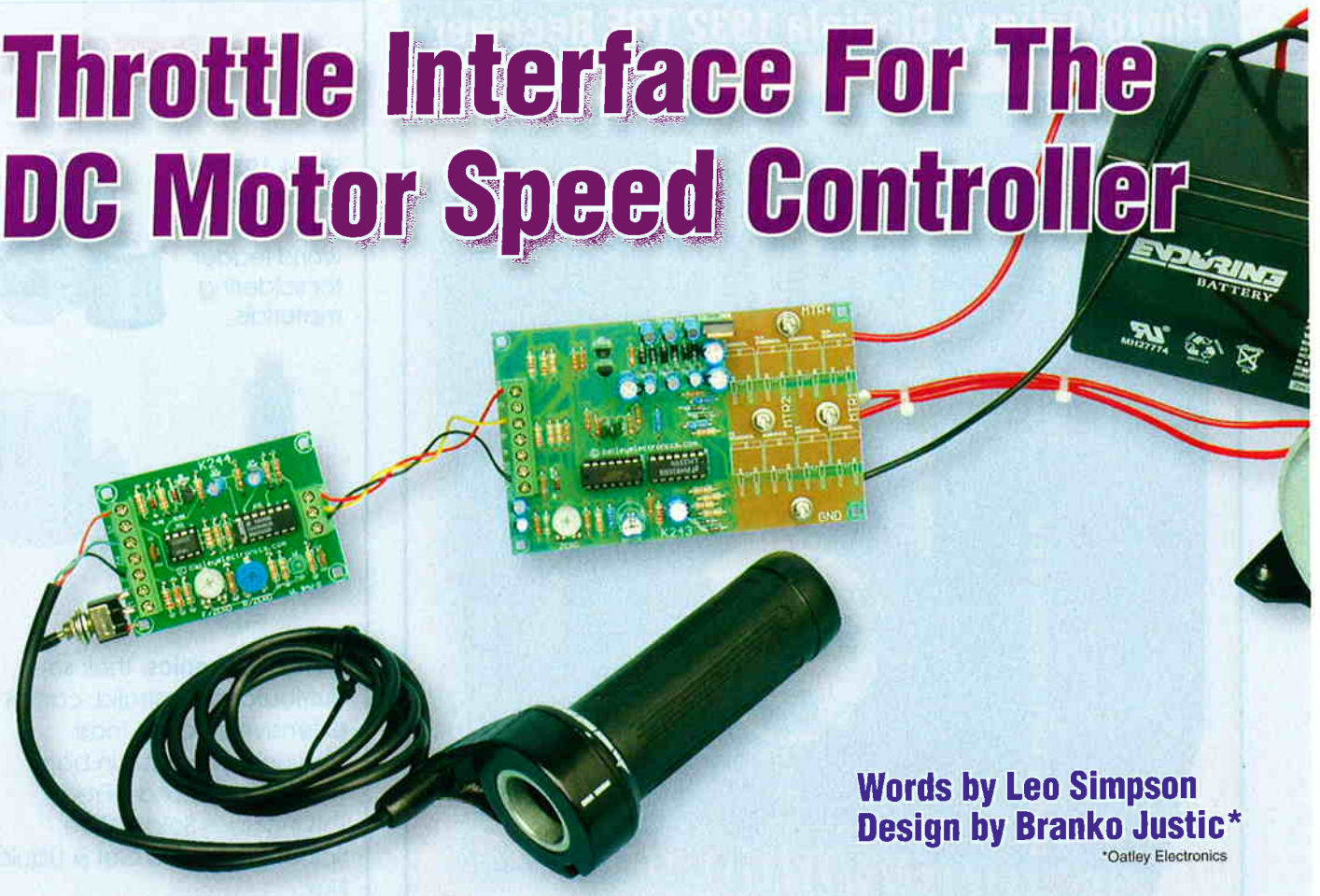
Throttle Interface For The DC Motor Speed Controller



Words by Leo Simpson
Design by Branko Justic*
*Oatley Electronics

Last month, we presented the High-Power Reversible DC Motor Speed Controller. Here is a companion controller which works with a motorcycle-style throttle control. It also features a forward/reverse switch to control the motor direction.

LAST MONTH'S DC Motor Speed Controller was designed to work from a joystick or a potentiometer that is normally centred. This has the virtue of simplicity but having the motor speed and direction under the control of a single potentiometer can be a problem in some applications. Therefore, this companion design was produced to allow a potentiometer to control only the motor speed while the motor direction is controlled by a forward/reverse toggle switch.

Furthermore, the potentiometer can be substituted with a spring-loaded motorcycle-style throttle control which could be just the ideal solution for applications like electric scooters, Go-karts, etc. This throttle control is shown in the photographs in this article.

The motorcycle-style throttle is based on a magnet and a Hall-effect IC to derive a control voltage. The more you rotate the throttle against its spring tension, the higher the control voltage fed to the input of the Throttle Interface circuit.

Circuit details

In effect, the interface circuit emulates the effect of the 10kΩ speed control pot used in last month's circuit. The DC voltage from the wiper of that 10kΩ speed pot determines the motor speed and direction. When the potentiometer is centred, the wiper voltage is +4.4V; when set for the maximum forward speed, this voltage is +6.4V and when set for maximum reverse speed it is +2V.

In order for the motor to go in the forward direction only, the control voltage range must be from +4.2V (motor stationary) to +6.4V (maximum speed). Similarly, for the reverse direction, the control voltage has to vary from +4.2V (stationary) to +2V for maximum speed. Therefore, the voltage range needed in both directions is around 2.2V. So the Throttle Interface circuit of Fig.1 has to produce this voltage range.

In essence, the circuit of Fig.1 uses two op amps as a voltage level translator and some CMOS analog gates to provide the forward-reverse function.

This Hall-effect throttle works just like the spring-loaded throttle on a motorcycle. It's ideal for use on electric scooters and Go-karts, etc.

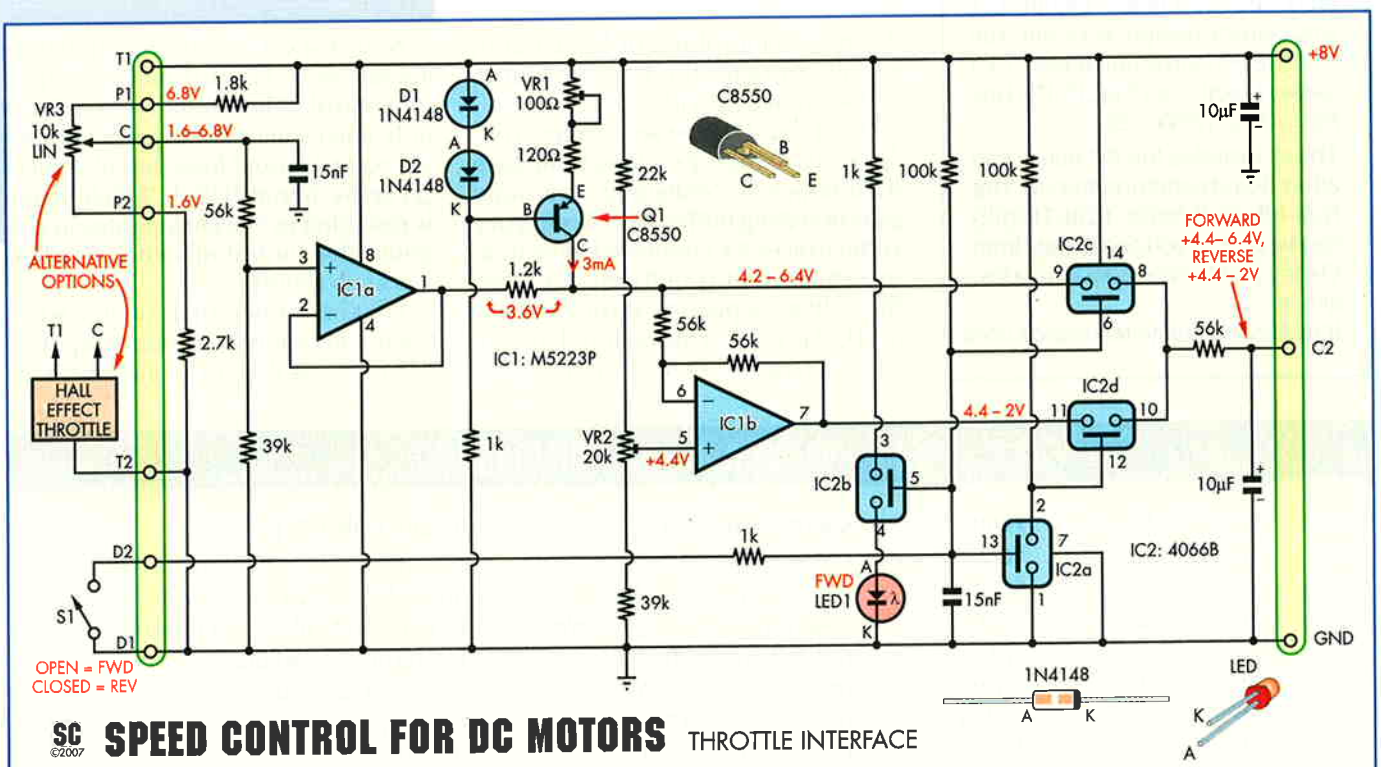
Let's have a look at how it works.

Consider a 10kΩ potentiometer connected to the input of the circuit so that its wiper is point C. If the potentiometer (or the alternative Hall-effect throttle control) is rotated over its full range, the voltage at the C input can vary between +1.6V and +6.8V. The attenuator comprising the 56kΩ and 68kΩ resistors reduces this range to between +0.65V and +2.8V. This is almost exactly the required control voltage range of around 2.2V.

This voltage is fed to op amp IC1a which is connected as a unity gain buffer (ie, the input and output voltages will be the same). So its output range will still be between +0.65V and +2.8V.

Transistor Q1, in conjunction with diodes D1 & D2, is connected as a constant current source with delivers 3mA into the output of IC1a via a 1.2kΩ resistor (a buffer can act as a sink or a source and in this case we are forcing IC1a to "swallow" 3mA while maintaining a constant output voltage). The result is that the output voltage range at the collector of Q1 is exactly 3.6V above the voltage at pin 1 of IC1a. And guess what? That means the voltage range at the collector of Q1 will be between +4.25V and +6.4V.

This is exactly the voltage range of



SC ©2007 **SPEED CONTROL FOR DC MOTORS** THROTTLE INTERFACE

Fig.1: this is the interface circuit for the Hall-effect throttle. Op amps IC1a & IC1b provide voltage level translation, while CMOS gates IC2a-IC2d provide the necessary switching for the forward-reverse function.

Parts List

1 PC board, code K244, 50 x 67mm
2 2-way 5mm screw terminal blocks
2 3-way 5mm screw terminal blocks
1 20kΩ trimpot (VR1)
1 100Ω trimpot (VR2)

Semiconductors
1 M5223P low-voltage dual op amp (IC1)
1 4066 quad analog switch (IC2)
1 C8550 PNP transistor
2 1N4148 signal diodes (D1, D2)
1 3mm green LED (LED1)

Capacitors
2 10µF 35V PC electrolytic
2 15nF (.015µF) ceramic or metallised polyester (greencap)

Resistors (0.25W, 1% or 5%)

2 100kΩ	1 1.8kΩ
4 56kΩ	1 1.2kΩ
2 39kΩ	2 1kΩ
1 22kΩ	1 120Ω
1 2.7kΩ	

Kit availability

This Throttle Interface project was produced by Oatley Electronics who own the design copyright. Kits (Cat. K244) can be purchased from Oatley Electronics Pty Ltd, PO Box 89, Oatley, NSW 2223.

The kit includes the PC board and all on-board components only. The Hall-effect throttle (Cat. Throt2) can be purchased separately from Oatley Electronics. See their website at:
http://www.oatleyelectronics.com

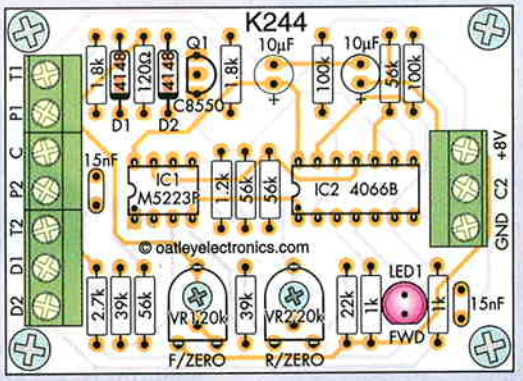
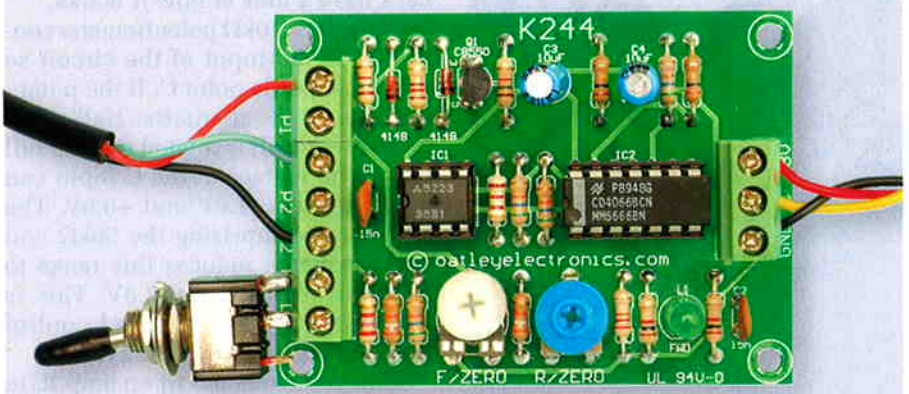


Fig.2: follow this parts layout to build the PC board. Make sure that all polarised parts are correctly oriented (ie, the ICs, diodes, Q1, LED1 and the electrolytic capacitors).



This full-size view shows the fully-assembled PC board. Refer to the wiring diagram (Fig.3) for the external wiring connections.

the speed control pot in last month's circuit. So that's the forward control voltage range provided for.

What about the reverse control voltage range? This is provided by op amp IC1b which is configured as a unity gain inverting buffer with a reference voltage of +4.4V connected to its non-inverting input (pin 5). By inverting the voltage appearing at the collector of Q1, it produces the required reverse control range of +4.4V to +2V.

Now that we have the required voltage ranges for forward and reverse motor control of last month's circuit, we only need some CMOS gates to select the correct output from the collector of Q1 or the output of IC1b. This function is provided by the analog gates in IC2, under the control of switch S1. This works as follows.

First, consider that switch S1 is open. This allows the control inputs of IC2a, IC2b & IC2c to be pulled "high"

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	4	56kΩ	green blue orange brown	green blue black red brown
❑	2	39kΩ	orange white orange brown	orange white black red brown
❑	1	22kΩ	red red orange brown	red red black red brown
❑	1	2.7kΩ	red violet red brown	red violet black brown brown
❑	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❑	1	1.2kΩ	brown red red brown	brown red black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	1	120Ω	brown red brown brown	brown red black black brown

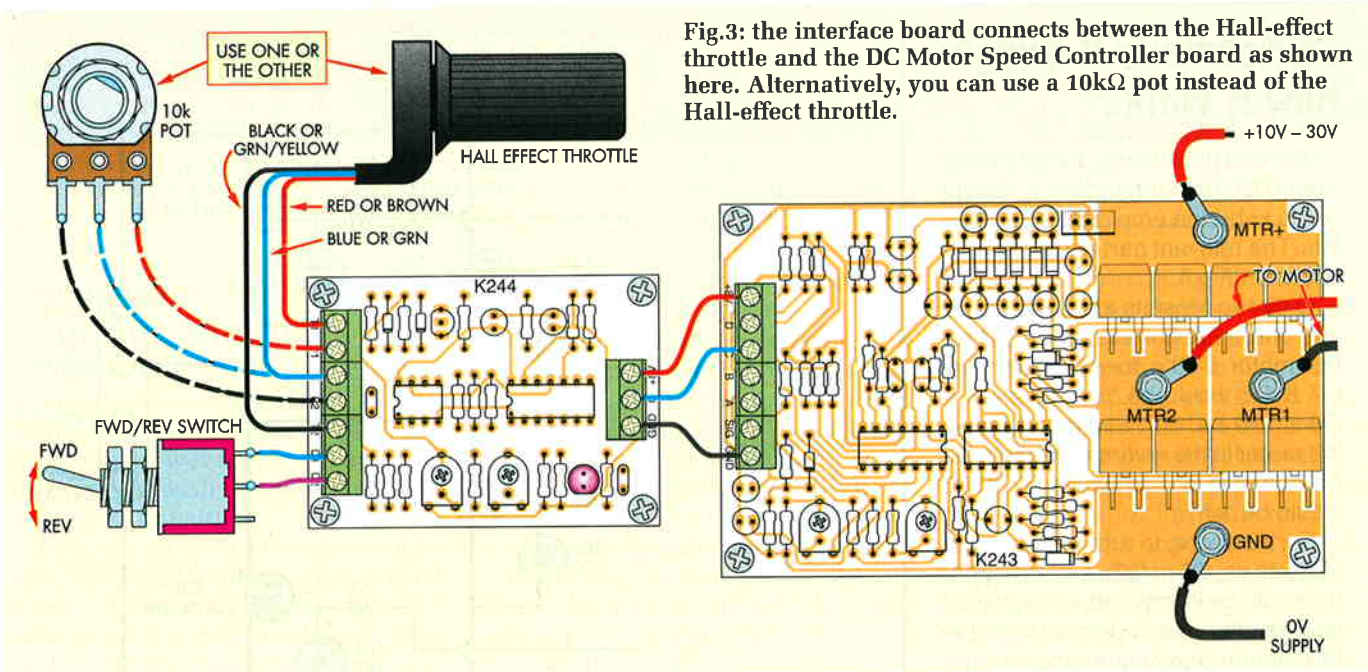


Fig.3: the interface board connects between the Hall-effect throttle and the DC Motor Speed Controller board as shown here. Alternatively, you can use a 10kΩ pot instead of the Hall-effect throttle.

by the associated 100kΩ resistor and therefore all these switches are "on". IC2b lights LED1, indicating a forward direction. The voltage at pin 2 of IC2a is "low" and therefore switch IC2d is "off". Since IC2c is "on", the forward control voltage from the collector of Q1 is applied to output terminal C2 via the 56kΩ resistor. The time delay provided by the 56kΩ and the 10µF capacitor is included to prevent any sudden changes in speed.

If switch S2 is now closed (ie, terminal D2 is grounded), the control inputs of IC2a, IC2b & IC2c are pulled low, switching those gates off and IC2d "on". This connects the reversing voltage from the output of IC1b to output C2 via the abovementioned 56kΩ resistor.

So there you are. That's how to use two op amps and four CMOS gates to do the job of the 10kΩ speed potentiometer from last month's circuit. Well, that's not quite right because we wanted to change the function but you now have the picture.

The only wrinkle to be added is that the low output voltage required from IC1a (ie, +0.65V or less) means that an ordinary dual op amp would not do the job. Instead, an M5223P low-voltage dual op amp is specified for this task.

Construction

All the components for the Throttle Interface, with the exception of the Throttle Control itself (or 10kΩ potentiometer VR3) and switch S1, are mounted on a PC board measuring 50 x 67mm. The component overlay is shown in Fig.2.

It is easiest to fit the components to the PC board in order of height. Start with signal diodes D1 & D2 and finish with the electrolytic capacitors, soldering and trimming the leads of each component as you go. Make sure the ICs and electrolytic capacitors go in the right way around.

Testing & adjusting

Before you can check the operation of the Throttle Interface, you need to have assembled and checked the operation of the DC Motor Speed Controller presented last month. In particular, you should connect it as shown last month, with a 10kΩ potentiometer connected to the B, C & D terminals of the PC board.

You also need to check that +8V is available at the output terminal on the main PC board.

With those checks verified, you can

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Switchmode H-bridge: How It Works

As noted last month, the DC Motor Speed Controller relies on a switchmode H-bridge employing four Mosfets. The relevant part of the circuit is shown in Fig.4.

Only two Mosfets are turned on at any one time. For example, to drive the motor in the forward direction, Q7 & Q6 would be "on" while Q5 & Q8 would be "off". Similarly, to drive the motor in the reverse direction, Q5 & Q8 would be "on" while Q7 & Q6 would be "off".

Furthermore, to turn on the upper Mosfets (ie, Q5 or Q7), a much higher gate voltage is required, as explained last month. This is demonstrated in the accompanying scope screen shots. For example, Scope 1 shows the gate voltage signals needed to turn on Q5 & Q8 while keeping Q7 & Q6 "off".

The higher amplitude yellow trace is the gate signal to Q5 and the lower amplitude blue trace is the gate signal to Q8. The purple trace and hidden green trace are the 0V gate signals to Q6 & Q8, keeping them "off".

Scope 2 shows the gate signals for reverse operation, where Q7 & Q6 are "on". The higher amplitude purple trace is the gate signal to Q7 and the lower amplitude green trace in the gate signal to Q6.

The yellow and hidden blue traces show the 0V gate signals to Q5 & Q8, keeping them off. In both scope screen shots the duty cycle of the gate signals is about 60%, corresponding to about half-speed operation.

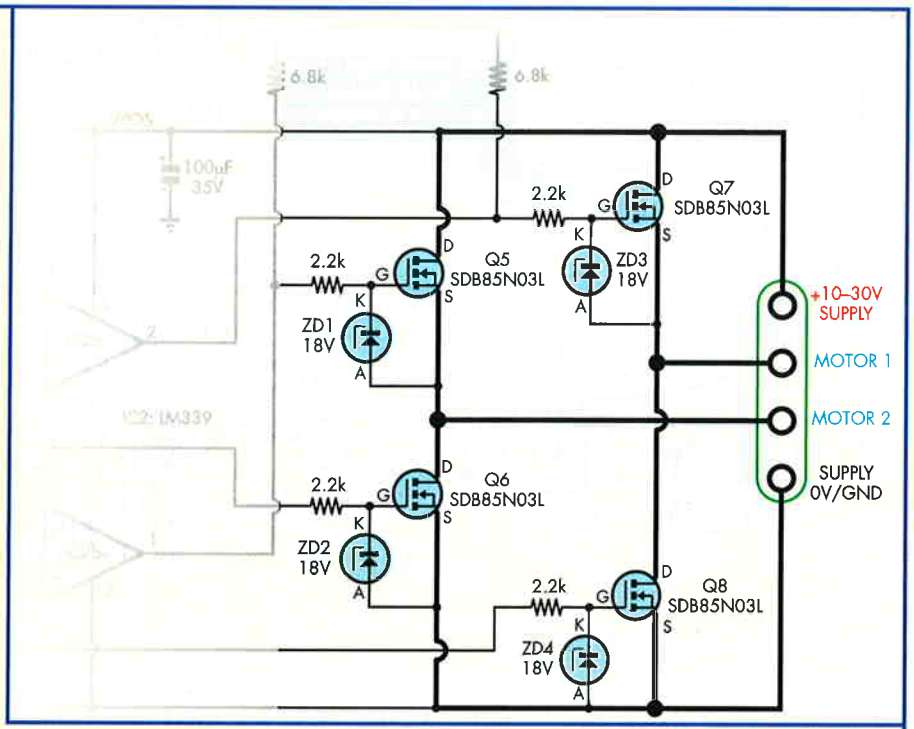
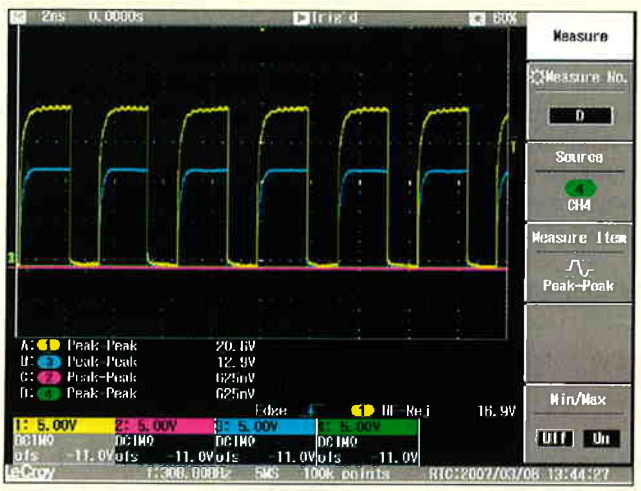
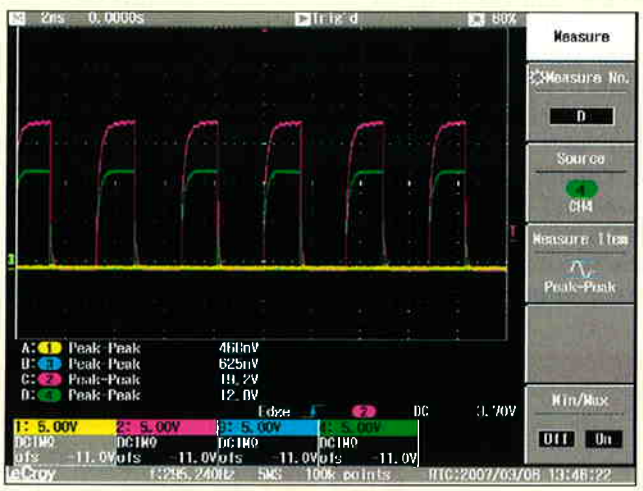


Fig.4: the switchmode H-bridge output stage of the DC Motor Speed Controller employs four power Mosfets but only two are turned on at any one time. Q7 & Q6 are turned on to drive the motor in one direction, while Q5 & Q8 are turned on to drive the motor in the other direction.



SCOPE 1



SCOPE 2

connect the Throttle Interface board to the main PC board, as shown in Fig.3.

If you use a "Hall-effect" throttle (from Oatley Electronics), it has to be connected to the "T1", "T2" & "C" terminals. If you use a standard potentiometer, it has to be connected to the "P1", "P2" & "C" terminals. **Do not connect both the 10kΩ pot and the Hall Effect throttle.**

A motor should be connected, to check overall operation. First, adjust VR1 so that the motor stops when the throttle (or pot.) is at its minimum speed setting and the switch is set for the Forward direction. That done, adjust VR2 so that the motor stops when the throttle (or pot.) is at its minimum speed setting and the switch is set for the Reverse direction. SC

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Upgrading the SC480 amplifier module

I built a couple of SC480 amplifiers a couple of years ago and they are still going strong and have never given any problems. However, I am an incurable tinkerer and wish to upgrade the output power transistors.

I heard a report from someone who used MJL15024/15025s with very good results, however I built the "plastic" version so I would need something with a TO-218 case. Also you mentioned MJL21193/4 and MJL1302A & MJL3281A in the original article. Can you recommend a particular transistor pair as a suitable starting point?

I know the measured performance of the stock amplifier is fantastic but I want to try a few tweaks. After all, that is the fun of DIY! Do you have a view on changing the quiescent current? (K. W., Newport, Vic).

- The only transistors we would suggest for an upgrade would be MJ21193/4. Leave the quiescent current at the specified setting.

Old EA frequency reference kit wanted

I'm after a pre-loved EA kit and that's the Low-Cost TV-Derived Frequency Reference, published in Electronics Australia in the October & November 1993 issues, by Jim Rowe. The kit's PC board number is 93TVF8.

Ideally, I'd prefer a working unit in its case but a "dead-un" would be considered. It's part of my excursion into high-precision and digital HF and VHF transmission techniques. It's a strange world looking at millihertz stabilities of TV carriers and E-layer ionospheric Doppler shifts.

Could any readers please let me know the pickup suburb/state and asking price on 0411 232 734. (C. S., Beacon Hill, NSW).

Modification to PIR sensor lights

I have a surveillance system at home. One of the features of this system is reliant on a sensor light and a relay that starts my video recorder. This works well until we get a momentary power failure. Most sensor lights have a feature that allows you to momentarily switch the power off and on so as to leave the light on. To return to sensor light mode, you have to switch off for about 20 seconds, then switch back on.

Is there a chance that one of your boffins could devise a circuit to allow the sensor light to return to sensor light status after a momentary power interruption? I would envisage an override switch if you wish to have the sensor light work normally. In addition to my needs, this would save people coming back from holidays and finding that the day they left on their 6-month journey, the power glitched and they've paid a bigger electricity bill than otherwise and contributed to global warming.

It's the simple things like this that drive me to buy and read your magazine and I hope that this could "spark" an article for me to build. (N. O., Moruya, NSW).

- That is an interesting suggestion but it would not be easy to implement. As you point out, these sensor lights do have a drawback with momentary power interruption. A more practical solution is to use a separate PIR sensor with relay output to switch the security light.

Smart card reader is mute

I purchased and built the Smart Card Reader/Programmer project from the July 2003 issue of SILICON CHIP but it does not work. The unit powers up and has both LEDs lit until Windows loads. Then the red LED goes out and the unit will not work.

I have tried it on three different computers with Windows 98, Me & XP loaded and used several different COM port cables, all to no avail. The several card writer programs cannot

Remote Control Extender Does Not Work With Foxtel

I have been using a Remote Control Extender as published in SILICON CHIP, October 2006. Recently, I upgraded my Optus analog TV to digital (using Foxtel equipment).

Initially, they installed a standard digital set-top box as the IQ boxes were out of stock. Immediately, the remote control barely worked via the extender, with maybe one trigger for every 10-20 presses. As soon as they swapped the box over to the IQ, the extender stopped working altogether, with not even a flicker from the receive confirm LED.

I have done a few tests on my Tektronix scope and found that the original analog remote carrier was on about 38.17kHz. The new digital remote is carried on almost exactly 36kHz. Is there any way to modify the circuit to allow for the 36kHz carrier frequency without losing the 38kHz ability? (S. T., via email).

- The carrier frequency can only be set to one value at a time and so the Remote Control Extender may not work with both 36kHz and 38kHz remotes at the same time without readjusting the carrier adjust trimpot VR1. You may be able to compromise with the adjustment so both remotes (with 36kHz and 38kHz carriers) work by setting the carrier between the 36kHz and 38kHz frequencies (eg, to 37kHz).

Ideally, however, you need two Remote Control Extenders to cover both carrier frequencies.

Regulated Power Supply For Amplifiers Wanted

I would like to suggest a regulated split rail power supply project for audio amplifiers. The design should have an adjustable voltage of as wide a range as possible but should be able to go up to ±37V and at least 3A of current.

There are many audio amplifier designs which I would imagine could benefit from the addition of a quality regulated supply, especially those with a high continuous current draw (such as class-A designs). The main reason I want a regulated supply is to get that extra bit of quality from the amplifier – to lower distortion. I would have thought that it would be impossible for any amplifier to have zero distortion (theoretically) unless the supply had a constant unvarying voltage.

The design should be able to be used for amplifiers in the small to mid-power range (say up to 60W) and perhaps the design could allow for a variable number of pass transistors to allow the current capacity to scale with the intended use. (P. T., via email).

● We have already designed a dual-rail fully regulated supply for amplifiers, in the August 1998 issue. It was used to power the 15W Class-A Stereo Amplifier.

As published, it delivered ±20V but it could be made adjustable, depending on the transformer input voltage. However, we do not regard such a power supply as providing any advantage for most class-B amplifier designs.

For a start, typical class B amplifiers have a PSRR (power supply rejection ratio) of 100dB or more, over a wide frequency range. This means that the supply rails can have quite large fluctuations with negligible effect on the amplifier's waveform and distortion performance. There is also no advantage in terms of residual hum and noise from the amplifier itself. Provided the supply voltage does not droop so low that the amplifier is pushed into clipping, the fluctuations will have negligible effect. Amplifier designers have been depending on this factor for decades.

In fact, there is a disadvantage in terms of power output. Any normal class B amplifier will have considerably higher music power output than its continuous power output (the ratio is referred to as "dynamic headroom") if it is used with an unregulated power supply. That is why all commercial amplifiers do not have regulated supplies.

Making the supply adjustable to cover a range of output voltages also presents a difficulty because if the supply is to have a big difference between the input and output DC voltages, it will need big heatsinks to dissipate the waste heat.

work unless the card writer works.

Can you give me some advice as to how to get the unit working please? G. E., via email).

● First up, note that you need a "pin-to-pin" serial cable for connection to a free 9-pin serial port on your PC.

Also, you mention that the project did not work with "several card writer programs". We have no knowledge of the project's use with any card writer programs other than the one described in the original article. This was IC-Prog, available from **www.ic-prog.com**

To test your completed project, use IC-Prog and follow the steps exactly as given in the instructions. In our experience, the most common problem is a fault in the gold card rather than in the project.

Class-D amplifiers get hot

Recently I was in the market for a modest home theatre amplifier to replace my Panasonic SA-HT70 which is rather large and clunky, has an inbuilt and unhackable DVD player, and lacks any auxiliary input for the internal surround decoder circuitry.

I was interested in a couple of very low-profile and fully-featured JVC models and searched the web for reviews. Apart from some negative comments about their automatic set-up features, the most common thread was the large amount of heat they produce, even when idling! That put me right off the products.

While browsing in K-Mart one day I came upon a Sansui SAN0310 amplifier complete with five surround speakers and a subwoofer for the princely sum of $129.00! "Can't go wrong at that price", I thought, and made my purchase.

I left the original Panasonic speakers in place and connected the new amplifier, taking immediate advantage of the coaxial and optical inputs. The Sansui amplifier gives a good account of itself as far as sound level goes but the lack of tone controls and the most bizarre "DSP" reverb effects I have ever heard (why would anyone listen to a movie in a mineshaft full of cotton-wool or in an empty cathedral?) make me sad when I think back to the excellent Sansui hifi gear of the 1970s and 1980s.

Anyway, you do get what you pay for, so I'm not complaining about that. What I do find objectionable is the large amount of heat the Sansui amplifier (and apparently the JVC class-D units) produce all the time. Even when 'Off' it gets quite hot, too hot for any gear sitting on top of it.

When the unit is turned off by the IR remote, the power LED blinks slowly – just what you need in front of your face when you're not using it. There is a power switch on the front panel which disconnects the power but unfortunately all your settings for delay, etc are lost when you power off this way. This Sansui amplifier will not have a long career in my set-up but will suffice for the time being.

I have not studied class-D much but I assume that the heat is being produced by the switchmode power supply, the class-D switching transistors and the low-pass filters in the six power amplifiers. How can it be claimed that class-D is 80% or so efficient when it wastes power so freely? This is an outrage in these times when we should be conserving energy.

I'd be most interested to hear your views on this topic. (J. R., via email).

● If your amplifier is 80% efficient at full output, that means that around 40W will be dissipated in the case

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Connecting PIR Sensors To An Alarm

I am a year-12 student at Ulladulla High School doing electronics and I am about to start my major project. It is going to be the PC-Controlled Burglar Alarm from the February 2006 issue of SILICON CHIP.

I have a problem with the PIRs for the sensors. They have a positive, negative and two alarm terminals. By contrast, the PC board in your magazine has positive, negative and one terminal for the alarm signal.

Does this mean that I put the two leads out of the PIR into the one on the board or do I need different PIRs? (N. P., Ulladulla, NSW).

● Many sensors have four terminals. Two terminals provide power for the sensor's internal circuits and are often marked "+" (positive) and "-" (negative). These two terminals connect to the "+12V" and "GND" outputs on the alarm board.

The second two terminals provide "normally open" (NO) and "normally closed" (NC) outputs. Only one of these must be connected and it's not important which one you choose. As described in the article, the NO or NC output of the sensor connects to one of the "ZONE" inputs on the alarm board.

When running the alarm software, be sure to select "N/O" or "N/C" in the "Configuration" panel to match the sensor wiring.

when everything is going flat chat. But at idle, you could well have 15-20W being dissipated in the case and if there are no conventional heatsinks on the outside or an internal fan, that means that it will become pretty warm.

However, there does not seem to be any good reason why the unit should still get hot when it is in standby mode. It may be that the power supply it quite simple and does not have a low-power rail to run the micro when it is "asleep".

Speed controller for a Go-Kart

I have built an electric Go-Kart for my two young boys. It is powered by two 24V 300W motors, one driving each rear wheel via a 2-stage chain reduction with the overall ratio chosen to limit top speed to about 12km/h.

In use, the motors easily reach their rated RPM even with an adult aboard, do not blow the 40A supply fuse and are not overly warm even after 30 minutes or so of use. So I am satisfied that the motors are working well within their ratings.

The speed controller used was originally constructed many years ago using a combination of ideas from various "Electronics Australia" and SILICON CHIP train controllers. The controller was originally used with a much smaller motor, with only three FETs, and was actually only used a few times.

When the controller was modified to suit the current application, the output stage was revised to include a 4093 and eight FETs. The FETs are mounted as two groups of four on two separate heatsinks but drive both motors connected in parallel. Reverse is provided via a heavy-duty relay. The idea of using the 4093 and eight FETs was based on information gained from reading some recent articles in SILICON CHIP.

The Go-Kart has been used many times over the last three or four months and is a "hit" with the boys but on two recent occasions the speed controller has failed. On both occasions, it is the output(s) from the 4093 driving the FET gates that has failed. The FETs test OK and no other components appear to have suffered.

As the same failure has occurred twice, I suspect that I have a design problem. The latest failure occurred on a fairly hot day so the problem may be temperature related. Can you suggest a fix? (A. C, Boronia Vic).

● As far as the circuit is concerned you are correct in saying the 4093 outputs are being overloaded. The outputs could be damaged in several ways. Firstly, the transient current required to drive four FET gates at the same time would be quite high.

The second and the most likely cause of the damage is that the switching transients at the FET drains can be coupled back to the gates (capacitively) to cause 4093 output damage.

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Converting A TV To An Oscilloscope

Have you ever designed a project that converts a miniature or portable B&W TV into an oscilloscope? It doesn't have to be fancy but just has to have some accuracy. Would this be possible? (K. S., Adelaide, SA).

● A TV CRO Adaptor was published by "Electronics Australia" in the May 1980 issue. This is only good for audio signals up to about 20kHz or so and is not calibrated.

These days, a much more practical approach would be to use our sound card interface for PCs together with software available over the internet to give a much better instrument. Two articles on this subject were published in the August 2002 issue of SILICON CHIP, together with a follow-up Circuit Notebook modification in May 2003.

By the way, Dick Smith Electronics has a 10MHz single-channel oscilloscope (Cat. Q1803) available for just $128.00

Thirdly, the gates of each FET are not isolated using 10Ω resistors (one resistor should be in each gate); the FETs tend to oscillate at switch-on without them.

As a minimum, we would recommend 10Ω gate resistors for each FET and a 12V zener diode between each gate and ground to clamp voltages above 12V. Further reliability would be gained by using the 4093 outputs to drive a complementary transistor buffer comprising a BC337 and BC327. The NPN BC337 transistor would have its collector to +12V and the PNP BC327 transistor would have its collector to 0V (ground).

Car radio noise cure

I noticed the letter asking for help with AM car radio noise in "Ask SILICON CHIP", January 2007. The usual cause for this is due to poor earthing to the car body at the antenna. (D. A., via email).

Serial I/O Controller & Analog Sampler

I want to use the Serial I/O Controller & Analog Sampler featured in November 2005 to monitor and control the charge/discharge of some large batteries, a total of 48VDC at 700A.

I want to monitor both temperature and voltage and switch the load and the charger during daylight and at night. To do this, I need to be able to locate the temperature sensor and LDR remotely. Is this OK or will long leads (up to five metres) cause a problem?

Also, what do I need to do to monitor up to 52V DC at the analog input port (normally 25V DC max)? Do I use a voltage divider? I assume software changes would be required in the Windows program as well but what about the PIC code? (K. K., via email).

● You should be able to mount the LDR remotely if you use shielded cable for the connection. Miniature 2-core microphone cable would be suitable. Wire the cable shield to ground. A 1kΩ resistor in series with pin 3 of the microcontroller will help to protect it in the event of static discharge to the long cable run.

The second analog input can be modified to accept 52V as follows:
(1). replace the 330kΩ resistor with 110kΩ.
(2). replace the 100kΩ trimpot (VR1) with a 2kΩ unit.
(3). Break the track between VR1 & LED4 (the ground connection) and insert an 11kΩ resistor in series with the pot.

The above changes will give an input range of about 49V-59V.

You will need to modify the Windows software to get the correct reading. The source code for the software is written in VB5. The PIC firmware should not require modification. SC

Notes & Errata

Programmable Ignition System For Cars Pt.2, April 2007: there are several corrections to the parts overlays and parts list as follows.
(1) the 4.7kΩ resistor shown to the right of REG1 in Figs.8-13 should be 47kΩ.
(2) the 10kΩ resistor shown immediately to the right of VR1 in Fig.10 should be 47kΩ.
(3) the resistor immediately to the right of Q4 in Figs.8-13 is 47kΩ.
(4) the parts list should show 3 x 100nF MKT polyester capacitors (not 1). A 10µF 16V PC electrolytic capacitor should also be added to the list.

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine. Devices or circuits described in SILICON CHIP may be covered by patents. SILICON CHIP disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. SILICON CHIP also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

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